# ENGINEERING

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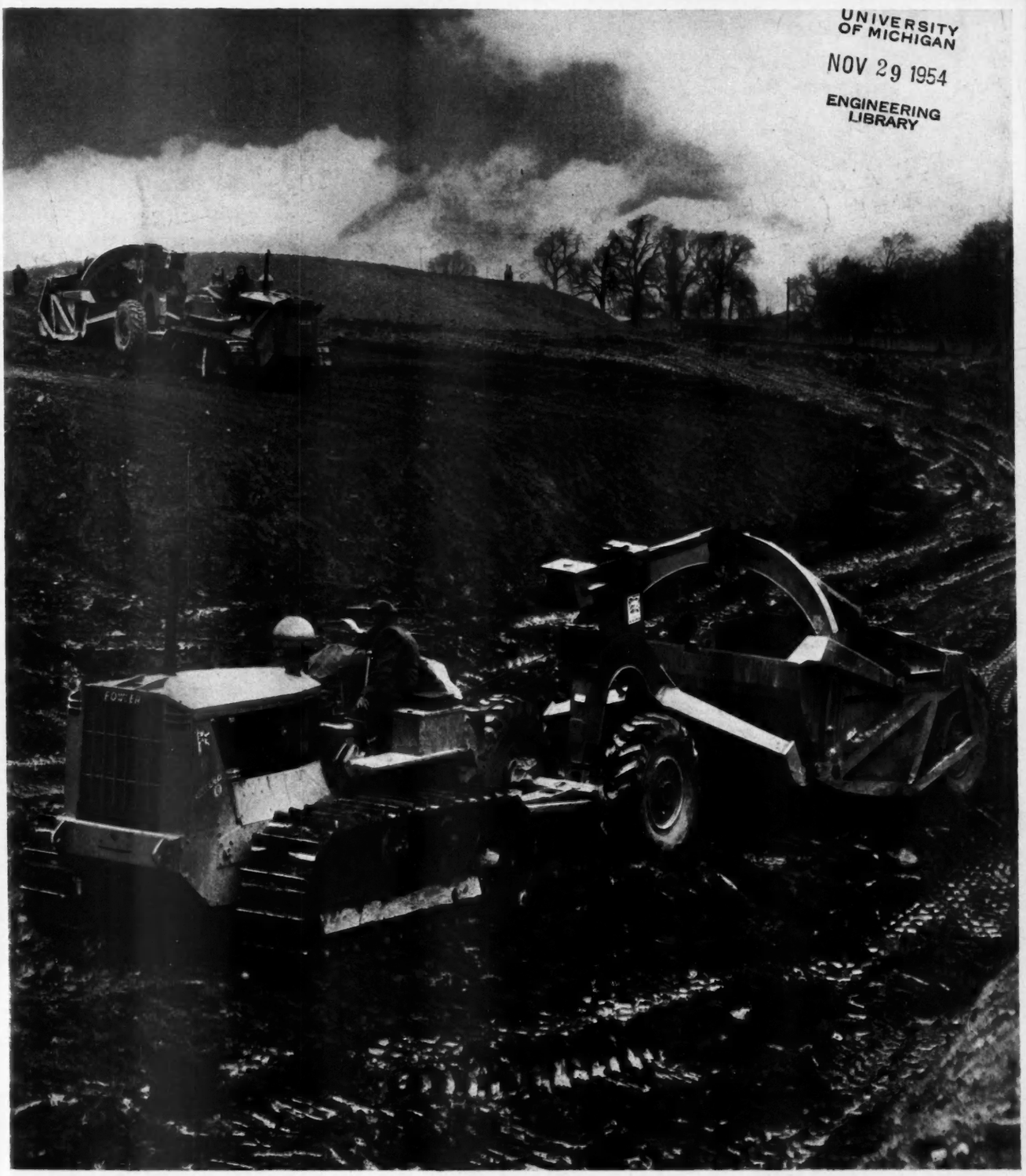

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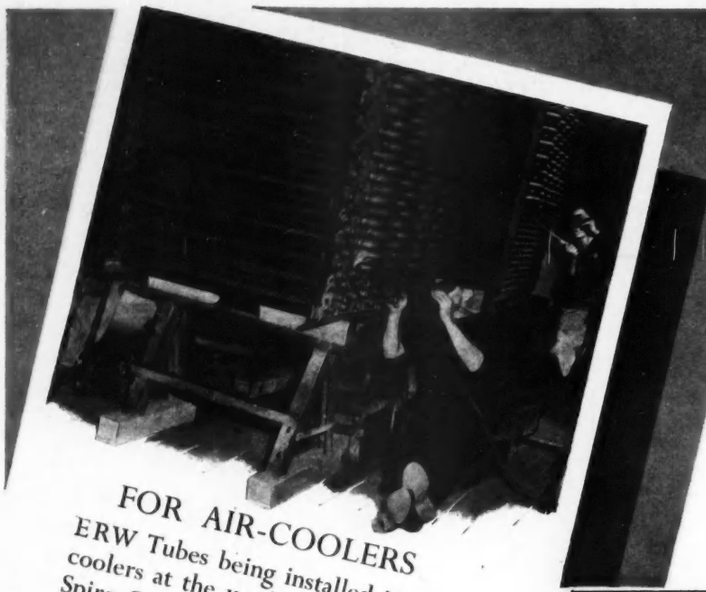

FOR AIR-COOLERS

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FOR WATER TUBE BOILERS

Installation of ERW Tubes in a water tube boiler at the works of Fraser & Fraser Ltd., Bromley-by-Bow, E.3

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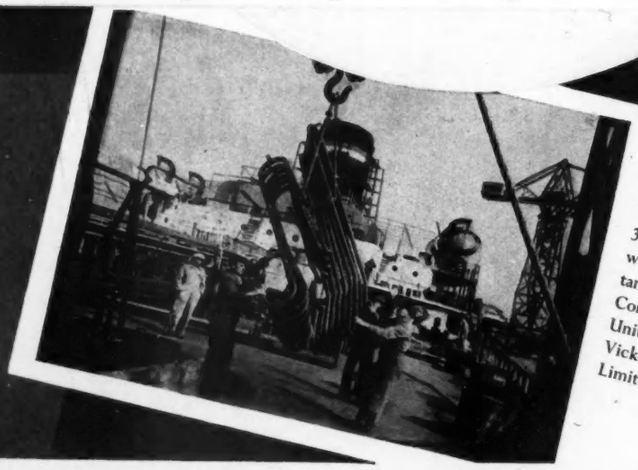

FOR OIL TANK HEATING COILS

30,000 ft. of ERW Tube was used in each of the tankers 'S.S. World Concord' and 'S.S. World Unity' built by Vickers Armstrongs Limited.

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# THE THERMIONIC VALVE

NEXT week what is officially described as the fiftieth anniversary of the invention of the thermionic valve is to be celebrated in London. Within the memory of many living persons this device has become the key component of all telecommunication projects, as a rectifier, amplifier and generator of high-frequency oscillations, and is also playing a leading part in that other field of activity which is conveniently known as electronics. As an invention it may be said to rank with the pump, the lathe, the condenser, the steam turbine and the internal-combustion engine.

The date chosen for these celebrations is Tuesday, November 16, 50 years to the day since John Ambrose Fleming applied for a patent (No. 24,850 of 1904) for "improvements in instruments for detecting and measuring alternating electric currents." Too much credit, however, must not accure to one worker (admittedly a leader) in this field; the efforts of others must receive their due.

In 1883, Edison found that if a metal plate were sealed in the bulb of a carbon filament lamp and connected to the positive terminal of an external circuit a current would flow when the lamp was lighted, while if it were connected to the negative terminal there would be no flow. Over 20 years later it occurred to Fleming that this effect could be used to rectify alternating currents of high frequency. To test the correctness of this assumption he placed a metal cylinder round a filament maintained at a positive potential, and thus produced the diode rectifier, which was the subject of his patent. In 1906 Lee de Forest an American experimentalist (who is still living) placed a third electrode between the cylinder and the filament, thus producing a triode with amplifying properties—properties which have since proved more important than those of Fleming's device. This third electrode was in the form of a grid and the flow of electrons from the filament to the anode could be controlled by altering its potential.

It is clear therefore that three workers—Edison, Fleming and de Forest—all made important contributions to the production of a practical thermionic valve. There were others, too, who played a part. Hittorf, as long ago as 1884, noticed that if the cathode of a vacuum tube were heated to incandescence a small electromotive force would pass considerable current, while later Wehnelt observed that if the filament were coated with certain oxides electronic emission was greatly augmented, and both sensitivity and ease of operation were increased. There were many others, who in one way or other added something to the common stock of knowledge, including Langmuir and his associates who studied valve-making materials and vacuum technique. In fact, team work, unorganised as yet, was beginning to compete with individual effort.

The stage was thus set for the utilisation of a new and, as it eventually proved, important tool with an ever-widening application. Progress was, however, slow and it required the first World War for the thermionic valve to be adopted on a large scale; and the second to secure and consolidate even greater advances. In mere numbers of types the valve is now an impressive device, since a short time ago it was estimated that 220 varieties had been added to the official numbered list in a period of five years.

In size, thermionic valves range from units suitable for use in transmitters of many kilowatts to the miniature patterns which have rendered possible the design of smaller and lighter equipment. They are employed to generate, amplify and detect relatively low frequency oscillations at one end of the scale and at the other to perform similar functions for pulses lasting one micro-second—two sets of conditions which are perhaps as widely different as they could possibly be.

These advances have, however, been due in large part to teams, and not to individuals working in isolation. This is, of course, a well-known feature of modern research and is a trend which is likely to continue whether it be in connection with further work on thermionic valves or on those substances the semi-mysterious properties of which were the subject of Mr. C. W. Oatley's recent address to the Radio Section of the Institution of Electrical Engineers on "New Materials and the Electrical Engineer."

Team work, however, like committee work, can usually only produce remarkable results when one member of the team has exceptional capacity for concentration, and is blessed with a genius for leaping intuitively to an apt and novel solution. Edison, Hittorf, Fleming, de Forest, Langmuir—they and others could not have achieved what they did but for the background of knowledge and experience against which they worked, but equally each would not now be remembered with pride and admiration if they had not possessed qualities of intellect and imagination which raised them above their colleagues and fellow men. The audience which will assemble at the Institution of Electrical Engineers next week to hear lectures by Sir Edward Appleton, Professor G. W. O. Howe and Dr. J. Thomson will not have the over-simplified view of scientific invention which is popularly held but the members of the audience will certainly derive inspiration from Fleming's contribution.

# Weekly Survey

## TRANSATLANTIC TELEPHONE CABLE

The submarine telephone cable which is shortly to be laid to link the United Kingdom, Canada and the United States will be of great historical and technical interest. Telegraphic communication was first established between the two continents in 1857, but the cable had a short life and it was not until 1866 that the North Atlantic was opened to electrical communication. At present, some 20 cables are in operation. In 1901 radio entered the field as a competitor, a commercial telegraph service being inaugurated in 1908, and nine years later a long-wave radio-telephone link was established. Short waves were introduced in 1928 and there are now 14 circuits operating on this system.

All these facilities have long been inadequate to satisfy traffic requirements. As long ago as 1919 a small group of American engineers under Dr. O. E. Buckley was organised to study the difficult problems involved in long deep-water submarine cables, and it is their work combined with a good deal of practical experience gained in the mean time, which may be justly said to form the basis of the new system. It will comprise two cables nearly 2,000 nautical miles long and will provide no less than 35 high-grade telephone circuits between the United Kingdom, Canada and the United States. It will therefore exceed anything that has been attempted hitherto.

The technical difficulties which have had to be overcome were formidable. This is clearly brought out in the paper which was read before the Institution of Electrical Engineers on Thursday, November 4, an abridged version of which is given on another page of this issue. The project has only been made possible by the development of submerged repeaters containing long-life valves and other special components. These repeaters, of which there will be 52, will be laid at depths up to 2,000 fathoms.

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## EXPANSION IN CIVIL ENGINEERING

There are at present grounds for greater optimism in the civil engineering and building industries than have existed for some time. Supplies of materials are rising and prices have reached a degree of stability comparable with the pre-war period. The good supply of materials was one of the reasons on which the Government have based their decision to bring to an end building licensing. Announcing this in the House recently the Minister of Works was able to say that, next year, there will be at least 100 million more bricks available and 500,000 tons of cement. As was reported in Weekly Survey last week, the steadiness of prices of materials, if not of wages, has enabled the London County Council to modify their standard form of contract, eliminating the fluctuations clause in respect of materials, so enabling contractors if they wish to tender on a fixed-price basis.

The contract for the Auckland Harbour Bridge has now been finally signed, as is reported in the Contracts column this week, for a £3,465,000 tender from Dorman Long and the Cleveland Bridge and Engineering Company; most of the sections will be rolled at Dorman Long's in Middlesbrough and the two companies are to share equally the tasks of fabrication and erection. The bridge, possibly the largest to be built since the 1930's, is expected to be opened by Christmas, 1958, or early in 1959.

The solution of the road congestion problem is another topic on which the future seems to be brighter. In the House last week a spokesman of the Ministry of Transport admitted that the case for improved roads was "indisputable" and that his Ministry was engaged on plans so that work could be put in hand as soon as expenditure was authorised. It is also believed that roads will be one of the subjects referred to in the Queen's Speech at the opening of the new Parliamentary Session.

The advent of this expansion in civil engineering and building has come in time to give point to this year's Public Works and Municipal Services Congress and Exhibition which is to open next week at Olympia. On show will be what is perhaps the largest display devoted to such equipment and plant held anywhere in the world, and manufacturers will be displaying the latest innovations in civil engineering appliances and machines. A report of some of these machines is begun elsewhere in this issue.

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## DOXFORD'S OPTIMISM

The chairman of William Doxford and Sons, Limited, Dr. E. P. Andreae, speaking at the recent annual general meeting of the company, commented that "new orders have been few and far between for some time past but there is a latent need for new ships which come within our range," and expressed confidence that Doxford would get their share of orders when they materialised. This confidence in the future is spreading in British yards, as we reported in a Weekly Survey note on October 29.

The main interest in Dr. Andreae's speech, however, lay in the reference to the company's large expansion programme, begun some ten years ago and now gathering momentum. Expenditure so far has amounted to £1¼ million, and a further £700,000 will be spent over the next few years. The programme involved a major extension to the engine works, including a new sub-assembly shop for the production of fuel valves and piston rods, a new brass shop and extensions to the foundry and crankshaft shop. A substantial part of the expenditure has been for the modernisation of plant and equipment, as "the introduction of welding methods and prefabrication in the early post-war years completely revolutionised shipbuilding practice." Doxford claim considerable success in their attempts to reduce costs by the introduction of modern methods and machinery, as well as an improvement in working conditions essential to ensure an adequate supply of labour. There is little doubt that the company's capital expenditure, though large in relation to the total issued capital, is as Dr. Andreae states "essential in order to ensure continuity of our business on an economic basis, even in bad times." Doxford's success in producing a supercharged version of their engine—the first was recently installed in a tanker—which develops on three cylinders as much power as the unsupercharged engine on four, is notable. The fact that they now have a new heavy-fuel-oil engine on test—the Doxford Diaphragm oil engine—suggests that they are keeping to the forefront of technical developments; they should therefore be in a strong competitive position when shipowners resume placing orders.

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## GERMAN COMPETITION

The extent to which the Germans have succeeded in increasing their exports in the past few years has been given much publicity in the United Kingdom by critics who have contrasted unfavourably the performance of British exporters. These, in turn, have often defended themselves by accusing the Germans of unfair trade practices. A new publication, "German Competition," by the Credit Insurance Association, Limited, helps to put matters into proper perspective. This shows that despite an increase of 27 per cent.—£336 millions—between 1951 and 1953 (when British exports actually declined by £9 millions), German exports per head of population were only 17 per cent. greater than in 1938, whereas British exports were 48 per cent greater.

The German success in the past few years has been partly due to some exceptional factors whose influence is not likely to be so strong in future. Internal demand, for example, has been kept down deliberately to encourage the export trade, but the recent pressure for higher wages shows that it will not be possible to maintain this policy. There has been greater scope for industrial expansion in Germany due to the fact that the labour force was under-employed. There are still a million unemployed in Western Germany, although the labour force, due to the influx of refugees from the East, has risen from 14·5 millions in 1951 to 16·5 millions. There is now a fear that there will be a shortage of skilled labour due to the fact that while older people are approaching retirement age, there will be a decline in the number of people at school-leaving age. The German export success has rested mainly on the performance in Western European markets, which have accounted for 66 per cent. of the increase since 1951. The relative weakness of British exports is largely due to import restrictions in the main Commonwealth markets. If British exporters can be criticised at all, it is on the ground that although they have succeeded in increasing exports to Western Europe, they have failed to pay sufficient attention to that market. The Germans themselves feel that they have been able to extend their exports only because the United Kingdom has been pre-occupied with other markets, and think that an energetic sales drive could lead to very much larger exports of British goods, even to Germany.

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## FLATTENING TREND OF OIL CONSUMPTION

European inland consumption of petroleum (excluding bunkers), which averaged 26·1 million tons in the immediate pre-war years, reached 64·9 million tons in 1953. Between 1948 and 1953 the average annual rate of increase was 12·3 per cent. per annum, but this was due to abnormally rapid industrial reconstruction and economic growth which has now fallen off. The increase in 1953 was only 10·4 per cent., and in 1954 is expected to be 7·6 per cent., falling further to 5·6 per cent. and 5·0 per cent., respectively, in 1955 and 1956. These are the estimates of the Oil Committee of the Organisation for European Economic Co-operation (O.E.E.C.), who in their 1954 Interim Report on Oil Refinery Expansion and Consumption Trends, present the results of a recent statistical inquiry.

Despite the flattening trend, the increase in European consumption by 1956 will nevertheless be considerable. Including bunkers, 87·6 million tons of petroleum is expected to be consumed, compared with 74·9 million tons in 1953. The largest increase will be in Diesel oil—19 per cent.—and there will be a slight change in the distribution of the various petroleum products. The proportion of Diesel oil will increase from 23·1 to 23·5 per cent., while the proportion of petrol will fall from 23·0 to 22·7 per cent. Fuel oil will still account for the highest proportion, 36·9 per cent., but this compares with 37·5 per cent. in 1953. Fuel oil is the principal form of petroleum used for industrial power, and the loss of ground is due to the greater use of public electricity supplies as well as to the reduced rate of industrial expansion in some countries.

The rate of increase in refining capacity will also slow down appreciably. In 1954, it is estimated that 93·5 million tons of crude oil will be processed, compared with 87·8 million tons in 1953; in 1956 the throughput will reach 99·1 million tons and it seems likely that capacity will be at least as fully used as is normal in the industry. Not all of the output of the European refineries can, however, be consumed in Europe. The Continent is already a net exporter of petroleum products—exporting 9·4 million tons and importing 8·2 million tons in 1953—and, according to the Report, the Refinery Expansion Programme has now reached the state when it has not only achieved the original aim of saving foreign currency but is also bringing in some

actual earnings of foreign currency. The United Kingdom will continue to have the largest share of the total European refinery capacity in 1956—30 per cent., but the increase of 16 per cent. above the 1953 level is 6 per cent. less than for Europe as a whole. It compares, however, with an estimated increase of only 12 per cent. in British inland consumption, so that there should be an appreciable increase in British exports. In this situation the difficulties which could arise from fluctuations in demand are, of course, increased but, as was mentioned in a note last week on the extensions at Fawley, the modern plant in British refineries gives a degree of flexibility in meeting market variations that should ensure profitable working in all conditions.

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## PAKISTAN'S BID FOR CAPITAL

Pakistan is making a bid to attract the foreign investor. As from September 1, 1954, unrestricted repatriation of investments, including ploughed-back profits, is being allowed and, in the event of nationalisation, "just and equitable" compensation will be remittable. Further, foreigners will be allowed to own up to 60 per cent. of capital in approved industries, a list of which will be issued shortly.

Industry in the United Kingdom is probably less interested in the terms of compensation and the possibility of easier conditions of repatriation of capital than in the possibility of eventual nationalisation. "Just and equitable" are words with varying shades of meaning depending on the content and the views of the assessors. Not many concerns are likely to be attracted to long-term investment if events can turn it into a short-term speculation with a costly and protracted legal wrangle at the end of it. The possibility of nationalisation is exceedingly difficult to assess for there are powerful political factors at work. The kind of complication which may arise can be seen from a glance at nearby India. The German consultants Krupps and Demag were retained earlier this year to report in collaboration with the Hindustan Steel Board on a plan for a 500,000 tons a year steel plant. At about the time when the preliminary report was under consideration by the Indian Government, the Russians let it be known that they were prepared to sell steel plant to that Government under a recently negotiated trade agreement. The terms they subsequently put forward were exceedingly attractive. They are reported to have offered to instal a works of half a million tons capacity a year for £62 a ton of capacity with export credit terms of 2½ per cent., compared with a British tender of £70 a ton with credit at 4 per cent. The Russians were clearly motivated to some extent by the possibility that their offer might persuade the Indian Government to set up a nationalised steel works. It is a thought, however, that the Russian bid could be no more than a competitive tender. There are few exactly parallel cases in history, but German consultants have recently reported in favour of a 50,000 tons a year unit for Pakistan.

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## NORTH AMERICAN RECOVERY

Fortunately for the export trade in this country the possibility of an end to the boom in exports to Australia is just about counterbalanced by a possibility of higher exports to North America. A recent report on economic conditions in the United States and Canada looked forward to a moderate up-turn of activity in the second half of this year. The high level of residential construction is scheduled to begin shortly and a slower rate of liquidation of inventories seems probable according to this survey. In recent weeks the portents for continued recovery had become more numerous. At the end of last month industrial production was moving up slowly towards the level achieved at the same time a year before, after several months of a fairly constant gap between comparative periods. Steel output at 75 per cent. of capacity was at its highest level since February and that useful indicator of economic activity, freight-car loadings, was also moving upward. Production of new models in the automobile industry will be stepped up during November and this will have a stimulating effect on the wide range of suppliers of components.

A similar survey by O.E.E.C. of the Canadian economy takes the view that total fixed capital outlay in 1954 will have been somewhat higher than for 1953. Consumption is expected to rise but private capital investment is expected to decline somewhat. On balance, therefore, there are better prospects for consumer goods, which will include motor-cars, but a slightly poorer outlook for imports of machinery. If the upswing in activity in the United States, however, were to become really substantial there is every likelihood that the Canadian economy would move upwards and in sympathy. Although private capital investment may decline, Government fixed asset formation is expected to increase. Development in the prairie provinces, including the expansion of the oil industry in Alberta, the development of atomic energy and progress with the St. Lawrence seaway, are all factors which could sustain the demand for heavy capital goods, even although the market for lighter equipment were slower to recover from the recent trough.

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## HYDRO-ELECTRICITY IN SCOTLAND

As will be gathered from an article which we publish on another page of this issue, a further stage has been reached in the utilisation of the waters of the River Conon and its tributaries for the generation of electricity in Scotland. This development consists of a power station with a capacity of 24 MW on Loch Luichart, with its associated civil engineering works, in the execution of which much ingenuity has been exercised and full advantage has been taken of new techniques. Eventually use will be made of the water from a catchment area of some 345 square miles in five stations with a total capacity of 107 MW and an annual output of 442 million kilowatt-hours. In this way it will be possible to save about 260,000 tons of coal per annum and to make a useful contribution to the electricity supply of the country, both locally and nationally.

This development has not been carried out without certain difficulties of a non-technical nature. Guardians of Scotland's scenery have had to be conciliated. That this has been successfully accomplished says much for the tact of the officials concerned. In fact, there is now a general admission that hydro-electric development need not, and in Scotland does not, do any harm to natural amenities—rather the contrary. In addition, some 250 miles of roads and footpaths have been constructed or reconstructed.

There remain the fishery interests, which exercise considerable influence in the North of Scotland Hydro-Electric Board's area. These interests have been considered in the construction of fish passes at many of the dams, often at great expense, but in addition, as the chairman (the Rt. Hon. Thomas Johnston) has pointed out, salmon hatcheries have been provided, lochs and rivers have been stocked, predatory fish have been cleaned out, and steps have been taken to discourage poaching.

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## SULPHURIC ACID AND CEMENT

The use of sulphuric acid has increased very greatly of recent years. One company alone utilises it in the manufacture of 12,000 products. In 1951, an acute shortage of sulphur occurred which caused much concern and, as a result of which, Imperial Chemical Industries, Limited, offered to license their process for making sulphuric acid from the anhydrite form of calcium sulphate. Eleven firms, including I.C.I., combined to form the United Sulphuric Acid Corporation, Limited, and proceeded to construct an acid plant at Widnes. The first unit of this plant is due to be commissioned in April, 1955, and when in full operation it will turn out approximately 7½ per cent. of Britain's present acid production. This will be divided among the member firms according to an agreed quota. A description of the plant is given elsewhere in this issue.

The anhydrite process requires costly plant and is expensive compared with production from sulphur direct. However, the clinker produced, ground and mixed with 5 per cent. of gypsum, gives a high-quality Portland cement the sale of which helps to offset the cost of the process. Also, all the materials used are indigenous and production will not be affected by import restrictions. The anhydrite itself, of which there are very large deposits, will come from a mine in Cumberland, and the coke, sand and shale, which are the other constituents, can all be obtained in the Widnes area.

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## TEXT-BOOKS THAT ARE NOT AVAILABLE

To fulfil the needs of students in the rubber industry for suitable text-books, the Institution of the Rubber Industry appointed a year ago a sub-committee, representing almost every section of the industry, to examine the available range of text-books and to consider what additional books were necessary.

The committee's first task was to decide what was wanted, and to find out as far as possible what books were already in preparation. It was not difficult to decide that two books on rubber technology were urgently required for students, covering principles and manufacturing methods, at licentiateship and associateship standard respectively; and that books on rubber chemistry and physics, preferably up to associateship standard, were also needed.

Much material of this kind already existed in the form of lecture notes, and it was agreed to ask appropriate institutions for their co-operation. The response is stated to have been very satisfactory, and it is likely that the staff of the National College and of the British Rubber Producers' Research Association will be able to provide what is needed. The committee also considered whether a book on rubber science was wanted but it seems probable that this need may be sufficiently covered by work already in hand overseas.

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## PAYING OTHERS TO DO RESEARCH

It is not possible for every engineering firm to have its own research laboratory. Apart from the capital cost involved, it is not easy to obtain and train a staff and then direct them to the best advantage. The amount of research or investigation required may fluctuate between quite wide limits. The range of problems that are liable to crop up may well be beyond the capabilities of a small staff.

When these conditions exist a firm can turn for help to a sponsored research establishment, and pay on a business basis for the services it requires. (The research associations meet a different need: being financed by the Government and by a whole group of firms in the industry, their work is generally planned to serve common interests.) A sponsored research establishment carries out work for its customers in confidence, and it has facilities and experience that are denied to the small or medium-size engineering firm. Being in constant and direct touch with industry it is not likely to permit its work to become divorced from practical needs. An article in this issue gives a glimpse of the kind of work one such establishment undertakes.

## THE JOINT IRON COUNCIL

### *Annual Banquet*

Lord Layton, chairman of the Consultative Assembly of the Council of Europe, referred to the decision, shortly to be reached, on what part Britain will play in the European Coal and Steel Community when he proposed the toast of "The Joint Iron Council" at the Council's annual banquet in London on November 2. He said that the plan was to reproduce in the Old World the kind of market that existed in the United States. It was a brave attempt, of great importance to the solidarity of Europe, and it was more likely to succeed if we in Britain contributed our wisdom and experience.

Mr. N. P. Newman, who has succeeded Sir Frederick Scopes as President of the Council, replied to the toast. He spoke of the difficulty experienced in persuading foundry employees to wear goggles, and he expressed his conviction that goggles added to, rather than decreased, the dangers. The chairman of the Iron and Steel Board, Sir Archibald Forbes, who replied to a toast to the Board, said that the conception that lay behind the Iron and Steel Act 1953 was of some measure of public supervision of an industry organised on private enterprise. It was worth remembering that some supervision by an independent authority had existed for 20 years, and a measure of approval existed for it in industry. The Board took no part in executive management; they supervised broad policy and looked after the interests of the consumer and producer. Much would depend on the success of the experiment. He hoped that people in the industry would make it known that they supported the Board. "It is in your interests that we should make a success of our job."

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## EDUCATION IN ELECTRONICS

### New Marconi College

A new training college to provide facilities for post-graduate studies in electronics and associated subjects has been built by Marconi's Wireless Telegraph Company, Limited, Chelmsford, Essex, and has recently been completed. The college possesses two lecture rooms, ten laboratories, a workshop, a drawing-office school, a technical library and an administrative block; and courses in radio, radar, television engineering and industrial electronics are provided for nearly one hundred students.

Places on these courses are available not only for graduate engineers and student apprentices of the company and representatives of the company's clients, but also for nominees of the Services, overseas governments and public bodies; private fee-paying students may also be accepted after these demands have been met.

Several courses are offered including one lasting 2½ months in the basic principles of electronics, but a number of courses are normally taken by each candidate and the maximum period of study is two years. The Principal of the college is Mr. R. E. Burnett, M.A., A.M.I.E.E., A.Inst.P., and the Director of Studies is Mr. R. G. Hulse, B.Sc.

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## CONTROL OF REPAIR GANGS BY RADIO

### Hydro-Electric Board's Tests

The North of Scotland Hydro-Electric Board are carrying out tests to discover the best sites for short-wave radio stations so that it will be possible for local headquarters to keep in touch with repair and maintenance gangs.

The first of these stations, which it is hoped will be brought into operation this winter, is to be installed near the top of the 2,500-ft. high Corrieyairack Pass, across which a 132-kV line is being erected from Fort Augustus to Glen Truim.

# RESEARCH AND INVESTIGATION TO ORDER

## THE FACILITIES AND WORK OF FULMER RESEARCH INSTITUTE

Fulmer Research Institute has now had seven years' experience investigating metallurgical and engineering problems on behalf of customers. The work in hand has grown steadily; equipment has been added to; and now a new engineering laboratory has been opened. The Duke of Edinburgh visited the laboratories, which are at Stoke Poges, Buckinghamshire, on November 2, and on the same day the Institute was thrown open for inspection by a large number of scientists and engineers.

The Institute undertakes, in addition to research, the investigation of materials or processes likely to improve or change existing industrial practice; the investigation of industrial problems dealing with service failures and the development of materials or equipment for special purposes; and routine mechanical testing and chemical analysis. A tour of the laboratories reveals that all the work is of immediate, or near-immediate, practical and commercial interest. This applies even to that fundamental research work to which Fulmer has devoted much of its facilities, namely, the extraction of metals, the constitution and properties of alloys, materials for high-temperature service, and the corrosion of metals and alloys.

### OXIDATION-RESISTANT STEELS

When a steel is required that will resist oxidation at elevated temperatures, a stainless steel is often chosen. If the cost of stainless steel is considered too high, however, the answer may lie in the new silicon-aluminium steels, which are not as expensive as stainless steel. They are readily worked and have the additional advantage that there is never likely to be any difficulty in obtaining the constituent elements. Steels containing silicon alone are unworkable even with silicon contents less than that desirable for optimum oxidation resistance, but the correct amount of aluminium permits a reduction in the silicon content sufficient to render the steel readily workable. It is believed that these silicon-aluminium steels will be useful for constructing heat exchangers.

Aluminium and its alloys are not usually thought of as suitable for resisting wear. Indeed, if two pieces are rubbed together a blackening of the area occurs. At Fulmer a protective film, easily applied, has been developed which successfully prevents this objectionable phenomenon. Service tests are being carried out on aluminium food containers.

Among the special strain gauges which have been designed at the Institute is a cantilever unit which was used to measure the relative movement between two sections of Mullardoch dam in Scotland. Another investigation was concerned with failures in service of H-type television aerials. Failures were occurring in high winds and corrosive atmospheres, usually at the reflector-tube attachment, and the problem was to determine the actual cause among several possible causes. For another client a study was made of residual stresses in tungsten-carbide rock-drill tips caused by the brazing operation.

### METALLURGY

Fulmer is particularly well equipped to deal with metallurgical problems. Some have already been mentioned and a brief summary of others may be of interest.

Improvements have been effected in commercial aluminium alloys. An aluminium-copper-cadmium alloy, developed as a result of an investigation of precipitation processes in alloys, shows a remarkable suitability for hot work, thus reducing fabrication costs compared with those of the conventional alloy. Its freedom from room-temperature ageing is advantageous since it is not necessary to form the alloy immediately after solution treatment, and refrigeration (required by other alloys of the Duralumin type) is unnecessary. The properties of the fully heat-treated alloy are at least equal to those of the normal high-strength alloys.

### EXTRACTION OF ALUMINIUM

A process for extracting aluminium of high purity from alloys produced by direct thermal reduction in an arc furnace is one of the most valuable developed at Fulmer. It can also be used to purify scrap or aluminium of commercial purity. Its advantages are its intrinsic simplicity, which will be reflected in lower capital costs, the fact that costly chemical processes for the purification of bauxite are eliminated, continuous operation is feasible, and while operating costs are likely to be no higher than in the present electrolytic method the cost of materials should be substantially reduced. Patent rights have already yielded a substantial dollar return. The commercial process depends on the reversible reaction between aluminium tetrachloride and any aluminium-bearing material to form volatile aluminium monochloride, which subsequently decomposes to give aluminium and its trichloride. This interesting development has arisen from work carried out by Dr. P. Gross.

### TITANIUM

Similar methods of catalytic distillation, based on a novel theoretical approach, are also being applied to the preparation of pure titanium and other metals. It is considered that present methods of producing titanium are unlikely to yield sufficient quantities at a price which will make extensive application of this valuable structural metal possible. Some titanium has been produced, though much work remains to be done.

Other metallurgical work which has been, or is being, conducted covers creep-resisting alloys, the protection of mild steel, new aluminium-tin bearing alloys, zirconium and uranium base alloys, corrosion and stress corrosion, the protection of aluminium from atmospheric corrosion, the production of wear-resistant and corrosion-resistant surfaces on otherwise soft or corrodible metals, hydrogen embrittlement of steels, high-speed steels, precision casting, etc.

### CERAMIC COATINGS—GAS TURBINES

The life of gas turbines is severely limited by the distortion and cracking of combustion chambers. The application of low-emissivity refractory coatings results in a considerable reduction in the amount of radiant heat absorbed from flames and thus a reduction in temperature of the walls of the combustion chamber. Composite coatings provide, in addition, protection of the underlying metal from oxidation. Service life is thereby increased.

The greatest benefit of these coatings is obtained where relatively luminous flames are employed. Contamination from the combustion products of vanadium and sulphur-bearing fuels, however, results in the lowering of the effectiveness of some coatings with time, and this problem requires further investigation.

There is no doubt that the Director of Research, Mr. E. A. G. Liddiard, M.A., F.I.M., and his staff are serving admirably the original aim of the founder, the late Colonel W. C. Devereux, that sponsored research in an independent research institute is an ideal way of ensuring rapid application of the latest scientific advances to manufacturing techniques.

(*Editorial comment in Weekly Survey*)

## PERSONAL

MR. W. LAWSON HURDMAN, M.Sc., M.I.Mech.E., M.Inst.Gas E., A.R.I.C., has joined the Owen Organisation as general production manager. He will operate from the head offices in Darlaston, South Staffordshire.

MR. P. G. HIEATT, M.I.E.E., M.Inst.F., a former system operation engineer, British Electricity Authority, Yorkshire Division, and subsequently personal assistant to the divisional controller, is retiring next month after more than 50 years of service in the electricity-supply industry.

MR. R. BANNERMAN, chief engineer in the Winchester Castle, retired from the service of the Union-Castle Mail Steamship Co. Ltd., 3 Fenchurch-street, London, E.C.3, on November 1. He joined the company as a junior engineer in September, 1914.

MR. B. SAMUELS, M.I.Mech.E., has retired from the service of Babcock & Wilcox Ltd., after 52 years of active association with steam generation.

MR. JOHN R. BINGHAM, who has been general manager of Joy-Sullivan Ltd., Greenock, for the past two years, has been appointed managing director of the company, which manufactures mining machinery and is the British subsidiary company of the Joy Manufacturing Co. of America. MR. G. H. BURR, European sales manager, in Paris, for the Joy Manufacturing Co. of America, has also been appointed to the board of Joy-Sullivan Ltd.

MR. G. A. RENDLE, B.Sc., M.I.E.E., has been appointed to the board of British Insulated Callender's Construction Co. Ltd. He becomes manager, cable contracts, in succession to MR. C. H. FRANKLAND, M.I.E.E., who, while remaining a director of the company, has undertaken special duties at the Trafford Park works of British Insulated Callender's (Submarine Cables) Ltd. MR. C. KIBBLEWHITE, M.I.E.E., has also been appointed to the board of the British Insulated Callender's Construction Co., Ltd., as an executive director.

MR. E. S. MACKAY has been appointed manager of the Leicester branch office of British Insulated Callender's Cables Ltd.

MR. W. D. D. FENTON, B.Sc., M.I.E.E., secretary and commercial engineer, North of Scotland Hydro-Electric Board, 16 Rothesay-terrace, Edinburgh, 3, is relinquishing this position at the end of 1954, on his appointment as deputy chief executive officer of the Uganda Electricity Board. On his arrival in Uganda, in January, he is to become deputy chairman of the board there.

MR. A. S. BISHOP has been appointed managing director of the Goodyear Tyre and Rubber Co. (Great Britain) Ltd., in succession to MR. W. A. HAZLETT, who will shortly complete his fiftieth year with the Goodyear Co. He has been appointed vice-president of the Goodyear Tire and Rubber Co. Inc., and is returning to the United States early next year.

MR. G. P. E. HOWARD, director and general works manager, Hayward Tyler & Co. Ltd., Luton, Bedfordshire, has now been made general sales manager of the company.

MR. ALFRED SCHOLES, F.R.I.C., F.I.M., a partner in the firm of Pattinson and Stead, public analysts and consulting metallurgists, has retired. He joined the firm as a pupil and became a partner 21 years ago.

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## BUSINESS CHANGES

A new company, SHELL RESEARCH, LTD., is being incorporated to take over the research assets and activities, in the United Kingdom, of the Royal Dutch Shell Group of oil companies formerly handled by the Shell Petroleum Co. Ltd. The new company, therefore, will assume control of the Thornton Research Centre, in Chester, and the Woodstock Agricultural Research Centre, in Kent. MR. H. BLOEMGARTEN will be chairman of the board of the new company, and DR. C. G. WILLIAMS, a director and general manager.

ALFRED HERBERT LTD., Edgwick, Coventry, announce that their London offices and showrooms, at 70 Vauxhall Bridge-road, S.W.1, have been reorganised and considerably enlarged.

THE FORD MOTOR CO. LTD., Dagenham, and RANSOMES, SIMS AND JEFFERIES LTD., Ipswich, have announced further developments in their joint working arrangement which commenced in 1945. As from January 1, 1955, the manufacture of all the farm machinery which the two companies have jointly developed for use with the Fordson Major tractor and for sale under the F-R trade mark, is to be taken over by Ransomes, Sims & Jefferies, together with the manufacture of all spare parts. In the home market the F-R range will continue to be marketed by Fordson dealers and Ransomes agents, actual distribution being carried out by Ransomes. The Ford Co. will continue to control overseas distribution of F-R machinery but Ransomes, as heretofore, will make available Ransomes farm machinery to all their overseas clients.

A new company specialising in farm machinery has been incorporated in the United Kingdom, namely, the NEW HOLLAND MACHINE CO. LTD., 7 Boston Manor-road, Brentford, Middlesex. The new company is associated with the American New Holland Machine Co. (Division of the Sperry Corporation), New Holland, Pennsylvania, and is a wholly-owned subsidiary company of the Sperry Gyroscope Co. Ltd., Great West-road, Brentford, Middlesex. The directors are MR. ARTHUR HILLIER, O.B.E., J.P. (chairman) and MR. ROBERT BROADBENT, M.I.Mech.E., M.I.P.E. The secretary is MR. A. K. BOSWELL, F.C.I.S., and the sales manager, MR. R. F. NAYLOR.

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## OBITUARY

*We regret to record the deaths of:*

MR. WILLIAM ROBERT BELDAM, F.I.R.I., on October 30, at his home at Belmont, Surrey, at the age of 71. He was a director of the Beldam Asbestos Co. Ltd., Lascar House, Hounslow, Middlesex, and other companies. Mr. Beldam joined his brother, Ernest, in the family business on his father's death in 1903 and his special interest lay in technical and production problems. In 1923 he became founder director of Auto-Klean Strainers Ltd. In later years he was also chairman of the Submerged Log Co., Ltd.

MR. EVELYN BOYS, M.C., F.C.I.S., on October 30, at the age of 70. He was secretary of the Northmet Power Co. from 1909 until his retirement in December, 1947, and was also a director or secretary of many of the undertakings associated with the Northmet Co. Mr. Boys was awarded the Military Cross while serving with the infantry in the war of 1914-18.

MR. EGBERTUS DINGEMAN KALIS, on October 30, at Utrecht, aged 64. He was chairman of the Westminster Dredging Co. Ltd., who have been responsible for some remarkable dredging and land-reclamation works in many parts of the world.

MR. JAMES WILLIAM SCHMIDT, on October 28, at Penrith, Cumberland, at the age of 82. Mr. Schmidt was chairman of the board of directors of William Ayrton & Co. Ltd., textile engineers, Manchester.

SIR JOHN EDWARD LENNARD-JONES, K.B.E., F.R.S., Sc.D. (Cantab.), D.Sc. (Manc.), on November 1, in hospital at Stoke-on-Trent, at the age of 60. He was Plummer Professor of Theoretical Chemistry in the University of Cambridge from 1932 until 1953, when he was appointed Principal of the University College of North Staffordshire. He was created a K.B.E. in 1946.

SIR WILLIAM ALAN AKERS, C.B.E., F.R.S., F.R.I.C., F.R.S.A., F.C.S., on November 1, at Alton, Hampshire, at the age of 66. He joined Brunner Mond & Co., Ltd., in 1911, and subsequently became a director of Imperial Chemical Industries Ltd. From December, 1941, until February, 1946, he served as director of atomic-energy research under the Department of Scientific and Industrial Research. He was created a Knight in 1946.

MR. HUBERT ALEXANDER GILL, C.M.G., M.A. (Cantab.), on November 3, at his home at Sanderstead, Surrey, at the age of 73. He served as President of the Chartered Institute of Patent Agents in 1925-26 and in 1939-40. Mr. Gill was created a C.M.G. in 1951.

MAJOR JOHN MAITLAND SALUSBURY-TRELAWNY, M.C., A.M.I.C.E., on November 2, at his home in Honiton, Devon, at the age of 62. He was for 20 years, from 1914 until 1934, in the Indian Railway Service.

CAPTAIN CLIVE WALTER BECKINGHAM, M.C., on November 4, at West Hartlepool, at the age of 76. He had been a director of the Furness Shipbuilding Co., Ltd., Haverton Hill-on-Tees, and other firms for upwards of 30 years. He was decorated with the Military Cross while serving with the Royal Artillery in the war of 1914-18.

MR. WILLIAM MARTER BURNE FURNISS, on November 8, at his home at Sedgley, Worcestershire, at the age of 47. He joined the Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton, in 1925 and, in January of this year was appointed managing director of the firm on the retirement, at the age of 83, of his father, Mr. William Marter Furniss, who was appointed managing director in 1942 and chairman in 1948.

## *Contracts*

### AUCKLAND HARBOUR BRIDGE

The Auckland Harbour Bridge Authority have finally accepted the joint tender of DORMAN LONG & CO. LTD., Middlesbrough, and the CLEVELAND BRIDGE AND ENGINEERING CO. LTD., DARLINGTON, and have received the necessary government authority to proceed immediately with the construction of a multi-span bridge across the harbour. The tender is for £3,465,000 and a period of 44 months is to be allowed for construction from the date when instructions are given to begin work. The tender was provisionally awarded to the two companies about two years ago, but the contract was not signed because sufficient capital for scheme as then proposed, over £4,250,000, could not be raised. The proposed bridge was described in considerable detail at the time in ENGINEERING (vol. 174, page 675, 1952) and it then had five traffic lanes in a 55-ft. roadway and two 6-ft. footways over a total length of 3,520 ft. In the scheme finally accepted the number of traffic lanes has been reduced from five to four, the footways are retained, but only the minimum of approach ways are to be constructed consistent with the long-term plans for shore development. All the money is to be raised internally within New Zealand and the costs of the sinking fund, interest, maintenance and administration are to be covered by toll charges. The consulting engineers to the Bridge Authority are Freeman, Fox and Partners, 68 Victoria-street, London, S.W.1.

**Diesel-Driven Generating Sets.** MIRRLEES, BICKERTON AND DAY LTD., Stockport, have received an order from the United Nations Korean Reconstruction Agency, through the Crown Agents, for two generating sets, to the value of £75,000. The engines are Mirrlees KSS 8 eight-cylinder pressure-charged, in-line Diesel engines with intercoolers, each with a continuous site rating of 1,512 b.h.p., driving alternators supplied by THE BRUSH ELECTRICAL ENGINEERING CO. LTD., and having a continuous site rating of 1,060 kW. They will be installed in the Samchok cement plant, Samchok, on the East coast of Korea.

**Aircraft for Royal Navy.** The Ministry of Supply has ordered 10 Dove aircraft, for use by the Royal Navy, from the DE HAVILLAND AIRCRAFT, ENGINE AND PROPELLER COMPANIES. The Naval designation of the type is Sea Devon C. Mk. 20. The aircraft, powered by D.H. Gipsy Queen 70 Mk. 2 engines, driving D.H. 1,000-size propellers, will be used for general communication services, and delivery will take place in the spring of 1955.

**Marine-Propulsion Units.** MODERN WHEEL DRIVE LIMITED, Lindo Lodge, Stanley Avenue, Chesham, and Slough, Buckinghamshire, have received another order for their multi-engine oil-operated main propulsion units for Canadian Service. This is a contract for a twin-engine Hindmarch/MWD oil-operated reverse-reduction gear for a new cargo vessel for the Whitepass and Yukon Corporation. The gear will take the power from two MIRRLEES JSS four-stroke Diesel engines, each rated at 955 b.h.p., at 800 r.p.m., with a gear ratio of 5 to 1, giving an output shaft speed of 160 r.p.m.

**Warships.** The Admiralty announce that H.M.S. Tiger will be completed by JOHN BROWN & CO. LTD., Clydebank, H.M.S. Blake, by the FAIRFIELD SHIPBUILDING AND ENGINEERING CO. LTD., Govan, and H.M.S. Defence, by SWAN, HUNTER, AND WIGHAM RICHARDSON LTD., Newcastle-upon-Tyne. The decision to proceed with the completion of these three cruisers was announced by the First Lord of the Admiralty, on October 15.

**Railway Wagons.** The British Transport Commission have placed contracts for the supply of railway wagons. Of the 20-ton ballast and sleeper-wagon class, 122 have been ordered from the GLOUCESTER RAILWAY CARRIAGE AND WAGON CO. LTD., Gloucester; 60 from the DERBYSHIRE CARRIAGE AND WAGON CO. LTD., Chesterfield; 70 from the CAMBRIAN WAGON & ENGINEERING CO. LTD., Maindy, Cardiff; and 152 from THE BUTTERLEY CO. LTD., Codnor Park, near Nottingham. Sixty 19-ton hopper ballast wagons, with vacuum brakes, have been ordered from the METROPOLITAN-CAMMELL CARRIAGE AND WAGON CO. LTD., Saltley, Birmingham, and six 25-ton well trolley wagons "Weltrol WBB" from HEAD, WRIGHTSON & CO. LTD., Thornaby-on-Tees.

**Glassware.** An order valued at 10,000 dols. has been placed by the University of California with Q.V.F. LTD., suppliers of "Visible Flow" glass pipeline and "Quickfit" industrial glassware, Stone, Staffordshire, for an 18-in. diameter glass pipeline, to be used for research purposes.

# TECHNICAL EVIDENCE AT THE COMET INQUIRY

*Continued from page* 588

The inquiry into the causes of the Mediterranean crashes of the Comet airliners "Yoke Peter" and "Yoke Yoke" continued at Church House, Westminster, on November 1.

On the question of bolts in the Comet Yoke Yoke, which were found to be missing at Rome, Sir Lionel Heald, Q.C., for the Crown, asked Sir Arnold Hall, director of the Royal Aircraft Establishment, "Can you say—and please do not go any further than you feel you are in a position to do—can you say whether these bolts could have had any deleterious effect on the aircraft which might have resulted in the crash off Naples?"

Sir Arnold replied that he thought that a de Havilland witness would be able to give a better opinion than he, but on the question, did it cause the crash, he thought that it did not. The bolts went back into place without any particular difficulty, proving that there had not been any undue distortion. There had not been any undue straining. Had there been any major distortion of the wing, maintenance engineers would have had considerable difficulty in putting the bolts back.

Speaking of the functions of the Air Registration Board and the Air Safety Board (he is a member of the latter), Sir Arnold said that the question of allowing Comets to fly after the Elba accident was largely in the hands of the Air Registration Board.

The effective step to prevent them continuing to fly would have been the withdrawal of the Certificate of Airworthiness by the Air Registration Board. That was not done. The Air Safety Board agreed with the decision not to withdraw it. If the Air Safety Board had felt that it was dangerous to keep the Comet flying it would have been their duty to inform the Minister of Transport and Civil Aviation.

## WHY C. OF A. WAS NOT WITHDRAWN

One of the reasons that the Air Safety Board did not suggest the withdrawal of the certificate was that the cause of the Elba disaster had not been established. The question had to be considered whether there was a chance of establishing, directly or indirectly, the cause. That seemed largely to depend on the chances of recovering a great part of the wreckage. It was his opinion at the time that the chances of recovering it were exceedingly remote.

"Now that we have established a cause or possible cause of this accident, there is nothing remarkable about the way the wreckage was distributed. I think that this is an exceptional accident because I believe it is the first aeroplane which failed because the pressure cabin disrupted in the centre of the fuselage."

Sir Arnold then described "this remarkable investigation" by Farnborough.

"I would like to publicly acknowledge the trade unions' co-operation, which was magnificent. They dropped their normal practices and we had men of one trade doing other work—in fact the whole thing was quite exceptional. I had completely disrupted my commitments to my other customers, which are many, but not one complained. It was desperately difficult."

Sir Lionel Heald: And you had great luck?—Yes.

Sir Arnold was asked by Lord Cohen for his reasons for agreeing to the recommendation that the Comet should be allowed to fly again after the Elba accident.

After referring again to the expected difficulty of recovering wreckage, Sir Arnold said that naval opinion at the time was that the Navy would be lucky to recover any wreckage in two years and would consider themselves lucky if they got anything at all.

## THE CALCUTTA ACCIDENT

The next question they had to consider was whether there was any connection between the Calcutta and Elba accidents.

The Board of Inquiry into the Calcutta accident had found that the aircraft was lost in storm. After the Elba accident he did not have any reason to doubt that finding.

"In the light of all the knowledge I and my colleagues have now got of the Comet aircraft we have not unnaturally reconsidered the Calcutta accident. We are in full agreement now, as we were then, with the findings of the court of inquiry. I have no doubt that that Comet fell victim to a storm which was of great severity."

In comparing the two accidents they considered that if there was any resemblance it might come within the scope of fire or explosion. From the date of the Calcutta accident, 50 or 60 modifications had been incorporated into the Comet, most of which were directed against the one possibility of fire or explosion.

Sir Arnold was asked by a member of the Commission whether as time wore on he considered the effect of sea water on wreckage from the Elba accident. He replied that it was recognised that were the wreckage to remain in the water for a considerable time the effect of corrosion would destroy the vital things, scratches and so on, for which they would be looking.

When the tailplane of Yoke Peter was recovered there was a perfect imprint of a newspaper on it, it having probably been impacted there when the aircraft crashed.

This section had been under water for five months. The imprint disappeared in a day or two when it was taken to Farnborough.

Sir Lionel Heald said that although it had been stated that there was no guarantee of safe fatigue life, was it possible by a basis of design, and programme of tests, to find the safe fatigue life of an aircraft?

Sir Arnold believed that it was possible and described what could be done. He thought it would be possible with a new aircraft to put it on test in the way that the Comet "Yoke Uncle" was tested at Farnborough.

He spoke of the primary points which carried the major load in flight and said that he did not think that every square inch of an aircraft needed to be tested.

Sir Lionel Heald: You do not take a pessimistic view about curing this trouble in the Comet?—I do not take a pessimistic view. I am sure that it can be cured and I hope it will be.

Of his decision to make fatigue tests and to acquire Yoke Uncle, Sir Arnold said, "In view of the fact that there had been no previous failure of this kind, it was an unusual step to take, but we had two crashes near the top of the climb and we took the decision because we had decided not to believe anything we were told."

Sir Arnold said that it would have seemed an "extremely curious story" to him if it had been suggested in 1952 that a pressurised aircraft like the Comet would disrupt through metal fatigue after 2,700 hours. "The detection of high-level fatigue is an extremely tricky business."

Cracks or no cracks, the aircraft would have disrupted at something like 27,000 hours—"three times our test"—at the very most.

After referring to "sectional stress tests" on aircraft in 1951, Sir Arnold stated that he would now advise the sacrifice of one complete aircraft of very new design to these tests.

Lord Cohen (chairman): That is what you are advising now?—Yes, I would advise that, depending upon how much the aircraft differed from other aircraft.

## COMET CAN BE STRENGTHENED

Resuming the inquiry on Tuesday, November 2, Sir Hartley Shawcross, Q.C., representing the de Havilland Company, asked Sir Arnold: "Having now had this very exhaustive examination and testing, are you able to say that provided that a thicker gauge skin is used and there is some strengthening of fuselage and wings, there is no inherent defect in the design of the Comet that would prevent it flying again?"

Sir Arnold replied: Providing steps are taken on the lines you have described, the Comet should go back into service and have a successful career.

Sir Hartley: And go back with a unique background of precautionary examination?—Yes.

Sir Hartley expressed the great appreciation of the de Havilland company for the remarkable investigation carried out at Farnborough under Sir Arnold's direction.

Sir Hartley then referred to another aircraft, without naming it, which had crashed in Italy on the same day as the Naples Comet disaster. He said that aircraft was flying to-day.

Sir Hartley: That aircraft has suffered quite a number of unexplained disasters?—I believe it has. But I must add that that aircraft is not British and it would not be within my knowledge as to what the manufacturers have done.

Sir Arnold agreed that the Comet was a safe aircraft, well designed and well made. He found many features of the Comet "quite excellent" and the aircraft was very well engineered—"an admirable aircraft."

Sir Hartley told Sir Arnold: "My clients are in complete agreement with you in regard to your general conclusions as to the cause of the disaster at Elba and the probable cause of the one at Naples being fatigue in the fuselage."

Sir Arnold agreed that in the light of knowledge that existed before the present inquiry, the de Havilland company were justified in thinking that the stress around the windows and cabin cut-outs was 50 per cent. of their ultimate strength.

"If I knew that the stress was 50 per cent. I would say that the cabin should have a safe life of 5,000 hours at least."

Sir Arnold agreed that the public might have got a wrong impression about fatigue from the book "No Highway" in which the fatigue life of an aircraft part had been predicted to within a very few hours. He agreed that in the present state of knowledge this was quite beyond the ability of engineers, mathematicians or metallurgists.

## LOAD TESTS FOR PRESSURE CABINS

Sir Hartley put a question relating to military aircraft. The discussion had been centring on repeated loading tests for pressure cabins, and when Sir Hartley suggested that Sir Arnold would know the requirements for military aircraft the Chairman suggested that there might be a danger of accidentally trespassing on confidential information about military aircraft.

"How far is it necessary for us to go into the requirements of military aircraft?" Lord Cohen asked Sir Hartley.

Sir Hartley had suggested to Sir Arnold that neither the Air Registration Board nor the Civil Aeronautics Authority of America, nor the International Civil Aviation Organisation, had hitherto required repeated loading tests for pressure cabins.

When Sir Arnold insisted that he did not know, Sir Hartley said "You would know, of course, what the requirements for military aircraft are. Has there been any requirement of repeated loading tests for them?"

"There has been in recent years," said Sir Arnold. But he felt he must point out that pressure cabins of military aircraft and pressure cabins of civil aircraft were "quite different animals."

Lord Brabazon of Tara, the next witness, said he had been chairman of the Air Registration Board since 1946. Part of their duties was the issuing of certificates of airworthiness and no civil aircraft could fly without the Board's consent.

"We never took the action of grounding the Comet. But I think it is fair to remember that if you grounded the whole type of every aircraft that had had an unexplained accident, you would scarcely have a machine in the air at all. We saw nothing in that accident which justified us in grounding it."

Lord Brabazon recalled that there had been two completely unexplained accidents to a previous aircraft, the Tudor. These accidents were never explained but the aeroplane had been gone through "with a fine comb," and a very large number of modifications were made.

The Tudor resumed flying and there had been no further trouble. It might well have been that in those modifications they had effected a cure, although the cause was never discovered.

After the Elba disaster there was a most thorough investigation of the Comet at London airport, as a result of which a large number of modifications were made.

Lord Brabazon then quoted from a letter the Air Registration Board had sent to the Minister, which included the paragraph "Although no definite reasons for the accident have been established, modifications are being embodied to cover everything that imagination has suggested as a likely cause of the disaster. When these modifications have been completed and flight tested the Board sees no reason why passenger services should not be resumed."

Lord Brabazon declared that nothing that he did, in the knowledge that he had after the Elba disaster, would he have changed.

## ADVENTUROUS PIONEERING SPIRIT

"There is something I would like to say which has nothing to do with my official position . . . I would like to say that you and your colleagues are charged in this inquiry to search here and there among the debris for troubles. I know perfectly well you will do it very well, but I do implore you not to lose sight of the wood because of the trees. Of course, we gave hostages to fate, but I cannot believe that this court of our country will censure us because we ventured. "You, my lord, would not have the aeronautical people in this country trail behind the world in craven fear lest they be censured in such a court as this for trying to lead the world.

"You know and I know the cause of this accident. It is due to the adventurous, pioneering spirit of our race. It has been like that in the past, it is like that in the present and I hope it will be in the future.

"In this inquiry there is nothing to be ashamed of; there is much more to be proud of.

"Everything within the realm of human knowledge and wisdom was put into this machine. The Aircraft Establishment tested every bit. They thought they would find weaknesses, but it was not found wanting.

"When we gave the certificate of airworthiness to these machines, they were airworthy. True, they deteriorated in a way no one on earth at the time could foretell; and they deteriorated, so I am led to understand, by a slowly developing molecular metallurgy fault.

"It is metallurgy, not aeronautics, that is in the dock at this inquiry."

Lord Brabazon declared: "I do hope that the threat of having to face such an inquiry as this, with all its publicity if anything goes wrong, will not stop adventurous spirits pioneering in the future."

Lord Cohen said that the inquiry was not solely concerned with seeking out trouble. Their duty was to find the cause of the accident and so far as that were concerned it looked as though it would be a comparatively simple task.

Sir Hartley referred to a "very famous" American aircraft with a pressurised cabin which he said he would not name.

Lord Brabazon agreed with Sir Hartley that shortly after the Elba disaster there had been accidents involving these aircraft in the Mediterranean, in the Atlantic and in the Gulf of Mexico.

Sir Hartley: Is that aircraft still flying?—Flying without any modifications as far as I know.

Sir Hartley then read an account of the discovery of a 24-inch crack in the fuselage of one of these American aircraft. As a result of this, the report stated, X-ray examinations had revealed similar cracks in two other aircraft of the same make.

The aircraft were operated by "perhaps the most famous operators named in the world." He brought this matter up to show that British aircraft were not the only ones in which cracks were discovered.

Sir Hartley: It looks as if this aircraft, one of the most famous in the world, has had a bit of fatigue trouble. Five unexplained disasters, but it is still flying. Would you agree that the British safety requirements are probably in advance of those in America or anywhere else in the world?—I am very glad to hear you say that, because I certainly think it is so.

Before the inquiry adjourned until Thursday, Sir Hartley returned to the question of the manufacturing cracks found in Comet Yoke Peter. He said he wanted to get the matter into perspective, and was not suggesting that the cracks ought to have been present.

He asked Sir Arnold Hall, "You do not suggest that these cracks caused either of these disasters?"

Sir Arnold replied that he was making no such allegation against them but he would have preferred that they were not there.

When the Comet crashes inquiry resumed in London to-day (Thursday), Sir Arnold Hall was questioned by Sir Hartley Shawcross about cracks found in the Comets.

## CAN ACCIDENTAL CRACKS LEAD TO FAILURE?

Referring to "a matter on which there may be some public anxiety," Sir Hartley asked Sir Arnold was it possible for a crack in an otherwise safe fuselage, that had arisen either in manufacture or, for example, from a workman using a screwdriver, to cause a catastrophic failure of the fuselage?

Sir Arnold replied that, provided the description "safe" meant that there were no points of very high concentration of stress in the fuselage, then it would not be possible for such cracks to cause a disaster.

"The travelling public may be in no burden of mind about that," he added.

Questioned by Sir Hartley about cracks which might be caused to an aircraft by the accidental dropping of a bolt from the roof of a hangar, Sir Arnold said that he was sure the public need have no alarm in their minds about such cracks as long as due regard was had in the design of the aircraft and provided the crack was not at a point of high stress concentration.

He added: "I do not think there is any dreadful difficulty in achieving the aim of making an aircraft proof against this kind of thing provided you go about it in the right way."

Sir Hartley: I am asking this as a general proposition. What I am trying to get clear is this. If you have an aircraft which is properly designed and built, by which I mean it contains no excessive or abnormal stress concentration, is it the case that a little crack of this kind of the order of 0·2 inch, caused accidentally, would imperil it?

Sir Arnold: It would not imperil it.

Sir Hartley: If, therefore, a mechanic on examining an aircraft found an accidental crack of this kind had occurred he would not have to ground the aircraft?—Oh, no.

If the aeroplane is such that 0·2 inch crack imperils it there must be something wrong about?—Yes.

Sir Hartley then went on to deal with the position of rivets at the point of disruption of Comet Yoke Peter and on the aircraft Yoke Uncle—the Comet tested in the tank.

He asked: "Is it right to say that there was no indication at all, either from the wreckage or in the tests in the tank, that the position of the rivets had caused weakness?"

Sir Arnold: Although it is certainly my opinion that these rivets were too close to the edge, they did not appear to have any effect. Had their effect been a major one, one would expect a disruption at that point on Yoke Uncle.

Sir Hartley said he now wished to go on to other matters which Sir Arnold had agreed had no bearing on the accidents but which might be important for the future.

Sir Arnold agreed that variations in cabin pressure were not a major factor in the present disaster.

The same applied to the force necessary to move the stick in the Comet's powered controls.

"We do regard this as a most undesirable feature, but we found no handling characteristics which were likely to cause a suitably-trained pilot to lose control under normal conditions. Our only feeling is that this might make it a little more easy to lose control under abnormal conditions."

Such conditions, said Sir Arnold, had undoubtedly existed in the Calcutta disaster to a Comet.

Sir Hartley stated that he was instructed this was not a matter that would present very great manufacturing difficulties to put right.

Sir Arnold agreed that he was probably right when Sir Hartley suggested that out of the pilots questioned whether the Comet's controls were better or worse than those of other aircraft in turbulent conditions, seven pilots had said they were better, five had said about the same and only four had said they were worse.

## ELECTRICAL AND HYDRAULIC SYSTEMS

Sir Hartley also cross-examined Sir Arnold on what he called "the tigers"—the electrical and hydraulic system of the aircraft.

Sir Arnold: You have to be careful to keep the tigers in separate cages. In the Comet the tigers lived in the same room—the equipment bay—but very careful and reasonable precautions have been taken. I see no reason why they should have come together.

Questioning Sir Arnold on the subject of "cures generally," Sir Hartley said, "I think you have told us already, these problems are by no means peculiar to Comet aircraft. Other pressurised aircraft will have to be looked at in the light of what we now know?"

Sir Arnold agreed.

Sir Hartley: I think you said that the Comet aircraft, although it was from one point of view a pioneering aircraft, did not introduce any really new factors?—No, not that I am aware of. It was of course the first large high-flying civil aircraft and was distinctly pioneering in that respect. But I would not like it to go out that the engineering problems were outrageously in advance of their time.

Sir Hartley: This is not simply putting an experimental aircraft into the air and expecting it to break up? It was doing something which was going a little further than previous aircraft had gone?—It seems to me it was doing a very enterprising thing, but by no means doing an outrageous thing.

## FATIGUE RESISTANCE OF HIGH-STRENGTH ALLOYS

It is the case, is it not, that these new high-strength light alloys are more brittle than the old ones?—Yes.

It is right, is it not, that the fatigue resistance does not increase in the same proportion as the tensile strength?—Yes.

I think you have agreed that there is no reason why, given proper attention, to these considerations, using a thicker gauge skin for instance, these and other aircraft flying in similar conditions should not be perfectly safe?—Not at all. I personally have a very great faith in the future of high-flying civil aircraft.

Dr. Percy B. Walker, head of the aircraft structures department at the Royal Aircraft Establishment, Farnborough, was recalled and cross-examined by Mr. L. G. Scarman, representing the Air Registration Board, about fatigue tests carried out on the Comet Yoke Uncle.

Asked by Mr. Scarman, "May one not tentatively argue that probable manufacturing cracks do not play any great part in shortening the fatigue life of the pressure cabin?" Dr. Walker replied, "You can argue that way, but I would not."

Mr. Scarman: Is it fair to say that one is entering realms where expert opinions may differ?—I can only speak for one expert opinion, I am afraid.

Dr. Walker agreed that no failure occurred in the pressure cabin tests earlier than at the equivalent of 9,000 hours.

He was asked by Mr. Scarman: Suppose that there had never been accidents at Elba or at Naples, but that there had been your Farnborough test. Would you, from that test alone, have deduced as probable a fatigue failure at 2,700 hours (the approximate flying-time completed by the Naples Comet)?

Dr. Walker: I should certainly have said we should not have agreed to an aircraft flying longer on that evidence.

He added: We should have said that any aircraft similar to the one tested—in other words any Comet aircraft—beyond that number of hours was not safe to fly.

Dr. Walker went on: We should have advised great caution and more experimental work, but the probability is we should not have agreed to the aircraft continuing flying.

"As a result of those tests," added Dr. Walker, "we should have regarded the Elba aircraft as definitely in danger and the Naples aircraft as either in danger or getting near to it."

## FUSELAGE LIFE VERY SHORT

Dr. Walker was asked by Mr. J. McCrindle, representing the British Air Line Pilot Association, what, on the basis of a failure at 9,000 hours, he would estimate as the maximum safe life for a Comet fuselage.

Dr. Walker replied: I shouldn't have thought it was worth flying at all.

After further questions from the chairman, Lord Cohen, Dr. Walker agreed that he felt after considering all the known failures that the total flying life of a pressurised Comet cabin would be "very short indeed."

Air Marshal Sir Victor Herbert Tait, operations director of B.O.A.C., said, in evidence, that it was within his knowledge that the first two Comet aircraft had been purchased by the Ministry of Supply under contracts which required the Comets to be to the Ministry's satisfaction. He could not say, however, whether the Royal Aircraft Establishment was acting as advisers to the Ministry in that matter.

Sir Hartley: Did you know that the Royal Aircraft Establishment was specifically consulted after the Elba accident, and before the Comets were put back into service, on the question whether there was any difficulty about allowing the Comets to resume the service?

Sir Victor: I know the Royal Aircraft Establishment had gone very much into the discussions and investigations into the accident.

Sir Victor said it was his belief that advantage was taken of the advice, experience and knowledge of all possible authorities in this country.

Sir Victor was asked whether after the Elba accident, and before the Comet resumed flying, the B.O.A.C. engineers and air navigation officers had put forward six points for the improvement of the Comet, with three of which the directors had agreed.

He replied: "That is quite correct but they had no relation to the Elba aircraft."

The inquiry then adjourned until Friday, November 5.

When the inquiry was resumed on Friday, Dr. Percy B. Walker described some experiments conducted on Meteor tailplanes in varying temperatures. He said that when the temperature had been cut down to −40 deg. they found that the life was actually increased to the order of 30 or 40 per cent., at the load levels at which they were working. His conclusion was that low temperatures increased the fatigue life but by only a quite small amount.

He was then questioned by Sir Hartley Shawcross on newspaper reports of his evidence of the previous day. Sir Hartley said that some reports suggested that Dr. Walker considered it had not been worth flying the Comet. Dr. Walker said it was not his intention to give that impression and he did not think that he actually had.

Sir Hartley: You did not, as a matter of fact. What you were saying was that in view of the lives of the Elba and Naples aircraft, and with the results produced in your tank tests, and having regard to the very wide range of scatter which is characteristic of the fatigue problem, the Comet aircraft as built at this time, was one which was bound to have a short life.

Sir Hartley said that for obvious economic reasons it would not be a profitable thing to produce an aircraft with such a short life as that, and Dr. Walker agreed.

Sir Hartley Shawcross: But you don't doubt, do you, that there is no reason why the Comet with

thicker gauge skin, and strengthening in the wings, should not have a long economic and successful life?

Dr. Walker: I have no doubt whatever on that point.

He agreed that there was nothing inherent in the design of the aircraft which would prevent it being made a perfectly safe machine.

Sir Hartley then questioned him about where the failure started on Comet Yoke Peter.

Dr. Walker said that in his opinion, once one corner of the fuselage by the window went, a second failure would be so close to the first that the further effect on the structure would be practically simultaneous.

When Sir Hartley suggested there had been several meetings between the de Havilland company and the establishment at Farnborough concerned with the testing of Comets, and that de Havilland had been fully co-operative, Dr. Walker said he thought de Havillands ought to have been more co-operative.

Sir Hartley: Do you remember in 1947 a meeting at which de Havilland's proposed to build a nose section for the purpose of testing.

Dr. Walker: I don't remember it.

Sir Hartley: Isn't it a little unsafe for you to say there ought to have been more co-operation if you don't know what co-operation there was? Did you know that a nose section was being specially built in 1947?—No.

Sir Hartley: Were you not told about it? You were the authority on fatigue at this establishment.—So you said.

Sir Hartley said that two men from the Farnborough Establishment attended a meeting at de Havilland to discuss strength-testing of aircraft and Dr. Walker said it was quite possible that it was such a long time ago that he did not remember.

Sir Hartley: It's not quite fair of you to say de Havilland did not co-operate as well as they should have done, if you don't know what meetings were held and what was discussed at them.

Dr. Walker: I can only give my impressions.

When the chairman suggested that Dr. Walker should tell the court what he thought de Havilland ought to have done, Dr. Walker replied, "I think they could have consulted us more than they did."

Sir Hartley then said that Dr. Walker's department, knowing about the fatigue tests which were being made at the de Havilland company, never at any time asked for fatigue tests on the pressure cabin.

Dr. Walker: It is quite possible we did not.

Sir Hartley: It is certain that you did not.

Dr. Walker: This was a civil aircraft . . .

Sir Hartley: Yes, being built to the satisfaction of your Ministry.

Sir Hartley said he was not trying to blame Dr. Walker or his department in any way. Sir Hartley then said that although Dr. Walker had not suggested to the Ministry or to de Havilland that the nose section should be submitted to fatigue tests, Dr. Walker's department did, in 1947, ask that the fuselage should be submitted to static double-loading tests.

Sir Hartley: Until de Havilland themselves decided to expose these aircraft to repeated loadings in 1953 your department had never sought to make that a requirement in the contract for the delivery of these two aircraft to your Ministry?

Dr. Walker: I think that is right.

Mr. Walter Tye, chief technical officer of the Air Registration Board, described the working of the Board and requirements needed before certificates of airworthiness were issued. He said pilots of the Board flew the Comet Mark 1 for 37 hours before a certificate of airworthiness was issued and since then they had flown 37 hours in production-line machines. The number of hours flown in Comets by the Board's observers numbered hundreds rather than tens.

*To be continued*

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## ELECTRICITY IN SEPTEMBER

### Increase Well Maintained

During September, 1954, 5,086 million kWh were sold by the British Electricity Authority to the Area Boards. This was an increase of 12 per cent. over the figure of September, 1953. When corrected for the weather, which was much colder than a year earlier, the increase was, however, 9·8 per cent. The amount of electricity sent out by the Area Boards was 4,976 million kWh, while 110 million kWh were supplied direct by the Central Authority. The increases in the amounts sent out, compared with the figures for the corresponding period in 1953, were 10·7 per cent. in the "mainly industrial" areas and 13 per cent. in the "mainly non-industrial" areas.

# PLANNING AND RUNNING A LARGE MACHINE SHOP

In a paper presented to the European Management Conference at Torquay last month, the advantages accruing to a firm which built its own machine tools were discussed. The paper was entitled "Automation—Implications for Management," and it was presented by Mr. Georges H. Raison on behalf of Mr. Pierre Bézier, both of Régie Nationale des Usines Renault.

The acquisition of all the machines necessary for a new manufacturing programme, the author said, was only possible if the machine tool industry could satisfy a heavy demand within a reasonable delivery time. Conversely, this industry could only exist if a sufficiently large group of customers were available so that a steady flow of orders could be maintained.

In 1946, the Renault Corporation started to carry out the machine-tool re-equipment for the Renault "4 CV" car. At that time it was impossible to go outside France for machines. Foreign currency available was barely sufficient to cover the purchase of indispensable machines manufactured, for the most part, in the United States, and the special-machine industry in France was not able to carry out the programme within the time available. It was therefore decided that the Renault tool-room would manufacture all special machines. They employed absolutely identical machine elements so as to simplify maintenance and repair.

### MACHINE UTILISATION

If a preliminary costing justified the use of equipment of high capital cost, those who used it would have constantly to ensure the maximum utilisation to reduce the overhead charges of operation and maintenance. Apart from accidental causes, two principal factors could reduce the output of a special machine: the time of loading and the time necessary to replace worn tools.

When automatic systems brought the workpiece to the point of machining and fixed it before the machine came into action, the loading time was practically nil. But for that to be possible the workpiece must present machined surfaces which permitted rapid and precise location. That was particularly the case with cylinder blocks, cylinder heads, certain crankshafts, and sometimes gearbox castings. It was necessary for the mechanisms for moving and clamping the workpiece to be specially designed. This could only be done at the expense of standardisation, with all that that involved in increasing manufacturing costs, increasing the delay in coming into service, and the possibility of recovering the cost. If, on the other hand, the workpiece were of irregular shape it was essential to hold it in a fixture which itself presented reference faces, allowing the whole workpiece and fixture to be located in the machine. This method required a conveyor for returning empty fixtures from the outlet side towards the input side of the machine.

### TOOLS

In order to reduce the time necessary for changing tools, Renault had for a long time mounted them on extensions, the length of which was adjusted in advance. This length was standardised for all tools of the same diameter in such a way that there was complete interchangeability between all the machines of the factory. Tools were not set and changed by the machine operators themselves but by setters who had racks and appropriate setting equipment. It was possible to classify all the tools of the machines in several groups and to allot a frequency of change to each of them. These were chosen to be multiples of the weakest. For the most important machines, Renault had placed a machining-cycle counter near the setter's post; this device was necessary not so much to define exactly the optimum wear of the tools as to warn the setter of those that would have to be changed. In that way all hold-ups of the machine through lack of replacement tools were avoided.

### ACCIDENTAL HOLD-UPS

Experience in the use of special machines had enabled the Corporation to lay down certain simple rules to reduce the consequences of unforeseen breakdowns. They attached great importance to the standardisation of their equipment. The machine elements were well known to their maintenance engineers. Faults could be rapidly diagnosed and repair or replacement of a defective part was simplified. All the spindles of the multiple heads were part of a large range of which a stock was held; the proportion of spindles outside the range was less than 2 per cent.

The results could be summed up in a few figures. Department 76 manufactured annually mechanical components for 120,000 "4CV" cars: it employed 1,420 machine tools; the team of maintenance engineers was 87; 66 of these repaired the 1,200 standard machine tools; the other 21 were sufficient for the maintenance of 200 special machines whose relative importance was approximately the same as that of the 1,200 others.

The stocks of components built up between operations or at the end of the line were obviously a source of expense since they immobilised capital. The interest on this capital was a kind of premium which was paid to insure against breakdowns. In general, a stock was held, at the end of the manufacturing line, equivalent to two days output. When a manufacturing line was composed of several transfer machines of great length, it was necessary to stock workpieces at intermediate positions, which enabled stoppage of work from thirty minutes to four hours to be overcome.

### SUPERVISION AND MAINTENANCE

For a long time it was considered by Renault that the personnel operating expensive and complicated machines ought to be provided with an extensive technical training, and that it would be necessary to envisage a high proportion of supervision and maintenance personnel. These two fears had been shown to be without foundation. Seven years' experience enabled them to state that the proportion of indirect personnel was smaller in the "4 CV" manufacturing department than in any other shop.

The total staff of the department of 2,800 people was in the following proportions, per cent.:—

| | |
|---|---|
| Engineers | 0·3 |
| Shop managers | 0·5 |
| Foremen | 2·1 |
| Charge-hands | 2·5 |
| Indirect labour | 18·0 |
| Maintenance engineers | 3·7 |
| Electricians | 1·5 |

A shop manager, for example, was responsible for the daily production of 580 sets of the following pieces: cylinder blocks, cylinder caps, oil pumps, water pumps, connecting rods and caps, pistons, sleeves, and various parts such as axles, etc. His shop employed 320 operatives controlled by nine foremen and ten charge-hands, roughly one supervisor to 20 workers. The setters numbered 41.

Machines could be controlled by operatives without any craft training provided they were hard-working, conscientious and cool-headed. The principal characteristics of the machines they operated must be explained to them, and it was found, generally speaking, that they adapted themselves very well, understood the functioning of the machine quickly and took a real interest in it.

# THE COLOMBO PLAN

## ENGINEERING CONTRIBUTION TO FAR-EASTERN LIVING STANDARDS

It was remarked in these columns on September 2, 1949, that " the population of the world is a function of the food supply in the sense that if people do not get enough to eat they will die." This stark statement is possibly distasteful to the majority of Western peoples. Their humanitarian sentiment would incline them to prefer the statement that one of the major problems facing the world is to increase the food supply at such a rate that it will keep in step with increasing populations. This may be admitted, but population control by malnutrition which has been in operation for centuries is still active. The average expectation of life in the countries of the Far East is greatly lower than in Europe. Primitive social conditions and practices have much to do with this, but inadequate food supply is an important factor.

The population of South and South-East Asia is some 600 million and is increasing at the rate of 10 million per year. It is stated in *Progress in Asia*, which was published last year by H.M. Stationery Office, that " by 1970 there will be about 150 million more people in South and South-East Asia to feed and clothe." This estimate is evidently based on the assumption that no important proportion of the 10 million individuals born each year dies from malnutrition. The purpose of the Colombo Plan is to endeavour to ensure that they don't. Malthus pointed out more than a hundred years ago that while population increases in a geometrical progression, food supply increases only in an arithmetical one. No matter what the starting conditions are, a geometrical progression will always overtake an arithmetical one. This cheerless fact does not, however, prove that the Colombo Plan is useless. The estimate of population of the area concerned in 1970, is pure speculation, and the objects of the Plan are by no means confined to the question of food supply. It aims at a general improvement in the standard of living, and if that is achieved it may have marked influence on population increase.

### WESTERN SCIENCE AIDS GROWTH OF EASTERN POPULATIONS

Humanitarian considerations had much influence on the inauguration of the Colombo Plan, but it was also largely determined by fears that a continuing low standard of living might result in social disturbance and political activities of an undesirable character. The peoples of the Far East have endured a social regime of primitive type for untold centuries, but modern methods of communication and the spread of information have induced dissatisfaction by making them aware of the differences between their lot and that of the more favoured West. In a sense, it is the duty of the peoples of the more advanced nations to attempt to improve the condition of the backward. Western science and practice, by introducing medical services and improved sanitation and water supplies have greatly reduced the death rate in primitive countries. Had the West not intervened, the conditions of a more primitive age would probably have endured, and it is but fair to suggest that those who introduced modern practices have some responsibility towards nations whose material resources have not kept pace with population growth.

The nations which inaugurated the Colombo Plan set out to " provide a frame-work within which an international co-operative effort could be promoted to assist the countries of the area to raise their living standards." The area referred to, which includes India, Pakistan, Burma, Ceylon, Indo-China and Indonesia, contains a quarter of the population of the world. The member countries of the plan, in addition to those being assisted, include Great Britain, Australia, New Zealand, Canada and the United States. The Western nations in which term Australia and New Zealand are being included, are providing finance and technical assistance, but much of the necessary capital expenditure is being undertaken by the countries which are being assisted. India for instance, which would not desire to be described as a backward country, although it has a serious over-population problem, spent £483 million on development projects in the period 1951-1953.

### AGRICULTURE AND ENGINEERING

So much has been written and said about the food problem in South-East Asia that a general impression has been created that the Colombo Plan is mainly concerned with agricultural questions. This idea is not entirely inaccurate, but a better impression of the main interest really involved is given by a remark in *Progress in Asia* to the effect that " the largest and most ambitious items in nearly every country's development programme under the Colombo Plan are major engineering projects." Many, perhaps most, of these are concerned with irrigation and involve the building of dams and the construction of distribution canals. The objects of the schemes are to increase, or improve, agricultural lands, but the work demanded is of an engineering character. An example is furnished by the Peechi Dam project in Southern India described in our issue of February 19, 1954. Furthermore, agricultural development demands agricultural machinery and the extent to which the engineering industry is involved is shown by the fact that by the year 1952-53, £82 millions worth of tractors and other agricultural machines had been supplied to the area.

Many of the irrigation schemes are naturally linked with power supply which is almost as important an item in an improved standard of living as is food. In Ceylon, for instance, the Gal Oya Dam scheme includes a 10,000-kW power station as well as the distribution and service canals designed to irrigate the so-called " dry zone " of the island lying to the north-east. Two-thirds of the population of some eight million is now crowded on the western coastal area. It is perhaps a matter for ironical comment on the way mankind manages his affairs that there are the remains of an extensive irrigation scheme in the dry zone, which was carried out more than a thousand years ago; some of it is being rehabilitated and incorporated in the new plan. It may be wondered if some of the works of present-day material civilisation will some day revert to jungle.

There are altogether nine multi-purpose projects, combining irrigation with power generation, in progress. Four are in India, three in Pakistan, one in Ceylon and one in Sumatra. Some dozen new thermal power stations are also being constructed and a number of port development schemes are under way. Technical assistance has been furnished by Western countries in connection with most of these schemes and plant and constructional machinery has been supplied. In many cases, dam building and excavation work has not involved the employment of the plant equipment which would have been necessary in more advanced countries. Cheap and abundant labour is available. The Tilaiya Dam in the north-eastern corner of India was built almost entirely with hand labour. A procedure of this kind is naturally not applicable to power-station equipment and machinery in general. Plant of this kind is either being presented, purchased under grants or provided from the resources of the country concerned. As already mentioned, many of the countries are doing their best to help themselves, but the magnitude of the outside assistance being rendered is indicated by the fact that the United Kingdom is releasing sterling balances to India, Pakistan and Ceylon at the rate of £42 million per year; has granted £10 million to Pakistan for the purchase of agricultural machinery and has supplied or promised £65 millions for development in Malaya, Singapore, North Borneo and Sarawak. The United States contribution to India and Pakistan in 1951-53 was £42·78 million.

The most recent publication dealing with the progress of the Colombo Plan is the " Report for 1953-54 by the Council for Technical Co-operation in South and South-East Asia " (H.M. Stationery Office. 1*s.* net). This is mainly concerned with the expert advisers from Western countries who are assisting in the carrying out of technical works and in the development of medical and agricultural services, and with the training being provided in the more advanced countries for individuals from the more backward. The report gives a list of the numbers of experts supplied up till June 30, 1954. The total was 263. Only 33 of these appear under the heading " engineering," but as two are listed under " power and fuel," 36 under " transport and communications," and 23 under " industry and trade," it is clear that engineering in its broad sense is widely represented. The largest number are concerned with " medical and health." The total number of trainees was 1,653, of which the largest contingent, 638, proceeded to the United Kingdom, of which 211 came under some branch of engineering. Australia, with 487 trainees, came second on the list.

### AN OMEN FOR THE WEST?

The fact that of the total number of experts, 23 were concerned with " industry and trade," carries an implication which in the long run may have an important bearing on the fortunes of this country. The Colombo Plan is concerned not only with improving food supplies but with improving the standard of living. One method of doing this is to establish manufacturing industries. In the past, the countries concerned have mainly depended on the export of raw materials, but as they have abundant and cheap labour which can be trained, their entry into the industrial field may result not only in the development of new and formidable competitors with the West, but in a fall in the demand for manufactured goods from Europe and America. A single example will illustrate this. The Indian government is building a factory planned for an output of 150 locomotives per year. A number of British firms are collaborating in this project and a number of British technicians have assisted. The development is no doubt a desirable one from the point of view of India, but that country has long been a valuable market for British-built locomotives.

The lesson which Britain must learn is clearly that more brains and man-power must be devoted to those products which require a high level of science, technology and skill, and correspondingly less to those products (generally those which are old-established) which can easily be made by the newly industrialised countries.

*Book Reviews*

# THE ART OF EXPERIMENT

**The Design and Analysis of Industrial Experiments.** Edited by OWEN L. DAVIES. Published for Imperial Chemical Industries, Limited, by *Oliver & Boyd, Limited*, 98 *Great Russell-street, London, W.C.*1. (63*s*.)

The value of statistical methods for planning and analysing experiments has been demonstrated so often and so convincingly during recent years as to need no further emphasis at this time. What is perhaps less widely appreciated, especially by industrial research teams who use these methods exceptionally rather than as a regular routine and can ill afford time and study to keep abreast of progress in applied statistical mathematics, is the variety of what may now be regarded as standard forms of procedure for use with particular types of investigation. Not only for typical lines of research, but also for the well-recognised stages of a scientific investigation, certain statistical techniques have been established as more suitable, or more easily and usefully applied, than others. To this extent at least, the use of technological statistics is something of an art, and those who wish to practise it can learn much from the successful work of others.

Herein resides the peculiar merit of this impressive volume which its authors modestly describe as a handbook. It owes its existence primarily to the fact that Imperial Chemical Industries, many years ago, were able to foresee the potentialities of statistical planning and analysis not only in their own, very extensive, research activities, but throughout the whole corpus of industrial development. To encourage the use of applied statistics within their own organisation they published, in the year 1947, a book entitled " Statistical Methods in Research and Production " which presented in a simple way those elements of statistical analysis that must be understood before the design of experiments can be undertaken. The new volume, while complete in itself, is a sequel to the other and contains so many references to its contents as to suggest that the first book is the most appropriate introduction to the second.

As might be expected from its provenance, the present book is mainly concerned with research in the chemical industry, and the statistical procedures described and discussed have in many cases been adapted or developed along special directions for application to chemical investigations, albeit in a connotation of that term broad enough to cover many subjects within the ordinary scope of physicists and engineers. Even beyond this limitation, technologists in other than the strictly chemical field will have little difficulty in envisaging types of experiment of close interest to themselves where the statistical methods discussed in special relation to chemical research can obviously be adapted to their own fields of industrial investigation, either immediately or with no more modification than a useful exercise can indicate. For instance, the first working chapter of the book (following an introductory outline of the whole text and its purpose) deals with the planning of simple comparative experiments and the submission of the results to significance testing. The principles involved in alternative statistical procedures are exemplified by numerical analyses of data derived from a series of measurements of the abrasion resistance of rubber, or the strength of a textile yarn. Not the least commendable feature of this book is its discussion of practical problems and the factors that determine the most appropriate means of approaching them by statistics.

Materials testing is, of course, only one of many types of investigation for which more than one method of statistical planning and analysis are appraised in this book The routine analysis of raw materials and finished products evidently justifies the attention it receives in a chapter devoted to the methods indicated by statistics for sampling and testing. Elsewhere the text deals with investigations into chemical processes, first on a laboratory scale, then with pilot plants and finally in full scale plant and production. All these stages have their counterparts in other industries than the chemical, and the appropriate statistical methods of planning, testing and analysis have their corresponding applications. Certain types of statistical procedure, here discussed at considerable length as being of special importance in relation to the chemical industry, have a much broader field of similar utility for very similar reasons. A case in point is the use of sequential tests of significance, in circumstances where observational data are obtained in individual succession or in successive groups. An appropriate statistical test is applied to the series of results as each comes to hand and the experiment may be terminated as soon as there is sufficient evidence to permit unmistakable conclusions to be drawn. The sequential principle can also be employed in the general strategy of experimental design. For either purpose it achieves the primary object, common to statistical procedure in general, of obtaining the required accurate information with the minimum of experimental effort.

This major objective of the statistical study of research is repeatedly emphasised throughout the book. It underlies an exposition, in two chapters, of the uses and limitations of randomised blocks and Latin Squares, or, where the experimental conditions are more restricted, of the more complex Incomplete Block Designs. Another important section of the book comprises four chapters devoted to factorial designs for investigating problems in which the effects of a number of different factors, on some property or process, require to be evaluated. Since such factors not only influence the final result both severally and in combination, it is manifestly economical so to design the experiments and to analyse their results as to determine, not only the individual effect of each variable factor, but also the interactions among them. The orthodox factorial design, already well established in agricultural and biological work, is often too elaborate and unnecessarily comprehensive for industrial experiments. Considerable attention has therefore been given in this book to fractional factorial designs, which enable the size of an experiment to be reduced to a fraction of that of a full factorial plan while nevertheless furnishing all the essential information being sought.

A highly important, though somewhat different, aspect of the economy offered by statistical design resides in the determination of the optimum conditions for operating an industrial process. Investigation of such problems commonly entails work on full-sized plant, so that experimenting is not only inherently costly but hampered by the need for avoiding interruptions of production. Within the I.C.I. organisation, processing is often on so large a scale that the potential rewards of economical operation are high enough to warrant most carefully planned experiments aimed at improvement. Several statistical methods have therefore been evolved to enable the search for optimum conditions of operation to be pursued with the minimum experimental effort, yet with the satisfying result of ensuring that the efficiency of the plant is progressively improved as the work proceeds. The somewhat advanced mathematical bases for these planning methods are developed in a long concluding chapter, a notable feature of the treatment being the use of local exploration techniques which permit the optimum to be specified with progressive precision and the operating conditions most suitable for practical plant operation to be determined.

This is a new approach to a class of problem that occurs throughout a wide industrial field and it is encouraging to know that the cited examples of " optimum conditions " determination are taken from successful applications in industrial chemistry that are likely, from the standpoint of the number of variables involved, to be at least as complex and difficult as elsewhere. It is satisfactory, too, to be assured that the practical examples with which the authors have illustrated each fresh statistical principle as it arises for consideration throughout the book have, in every case, been proved of value within their own experience. A number of these examples confirm, what has already been implied, that the compilers of this book have kept in mind the needs of many technologists other than the chemists to whom their work is primarily addressed. In particular, they are aware that comparable problems are encountered in the research, production, inspection and perhaps the administrative departments of engineering organisations. To the mathematically competent among such workers, as well as to statistical theorists and students at a fairly advanced level, this book can be cordially recommended as a source of instruction and practical guidance.

**Strength of Materials.** By G. H. RYDER. *Cleaver-Hume Press, Limited*, 42*a South Audley-street, London, W.*1. (21*s*.)

This text-book has been written to cover the syllabuses of universities in the subject of strength of materials, and the standard of mathematics required is that which would normally be expected of students pursuing such a course of study as the book provides, along with a parallel course of mathematics. It is therefore gratifying to find the underlying principles explained in a style that leads to the logical development of ideas and the shortest way to the solution of a given problem. Further, the quality of conciseness has been greatly facilitated by the use of numerous diagrams.

After expounding the various types of stress, in the first four of the 18 chapters in the book, the author extends these considerations to the case of bending stress, shearing stress in beams, and torsion of shafts, up to the question of a shaft of rectangular cross-section, which is dealt with rather briefly. The line separating this subject from the theory of structures is an arbitrary one, and advantage is taken of this by the inclusion of continuous beams in the discussion of beams, whether simply supported or built-in, and of curved bars and rigid frames. Alternative methods find a place at appropriate stages of the work, as, for instance, in the section on the deflection of curved bars, where the problem is solved, first, by the direct method and, second, by means of Castigliano's theorem. Chapters on springs and struts precede the more advanced part of the treatment, which falls under the main headings of cylinders and spheres, rotating discs and cylinders, circular plates, and vibrations and the critical speeds of a shaft.

The requisite faculty of applying theoretical results to the solution of prescribed problems, which is a source of weakness with many students, can be developed by study of the numerous illustrative examples in the text, and the exercises, of which there are more than 300, that have been culled from previous examination papers of London University and other sources. Some references to other books are given, but the subject-matter merits a more comprehensive list, for purposes of guidance to information on how practical problems have been brought within the scope of the available mathematical equipment; and some readers would no doubt have welcomed a more detailed account of the testing of materials, to which the final chapter has been devoted.

* * *

In describing the Tangye fuel-pump exhibited at the Baghdad Trade Fair, in our issue of October 22 (page 538), it was stated that the local fuels had a " low pour point." This should, of course, have been a " high pour point " as otherwise the heater would not be required.

## BOOKS RECEIVED

*Some of the books noticed in the Books Received column are selected for extended review in later issues of* ENGINEERING.

**The Load on Top Management—Can It Be Reduced?** By L. URWICK. *Urwick, Orr and Partners, Limited, Urwick House, 29 Hertford-street, London, W.1.* (2*s.*)
This booklet is an expansion of views contributed by Lt.-Col. Urwick to a panel review held at the European Management Conference, Torquay, October, 1954. He discusses the reasons for, and the effect of, an increasing work load on managers, and the steps which can be taken to reduce this load.

**Treatment and Disposal of Sewage Sludge.** Ministry of Housing and Local Government. *H.M. Stationery Office, Kingsway, London, W.C.2.* (2*s.* 6*d.*)
This is a report of an informal working party, and is based on a wide survey of experience in this country and abroad. The subjects included are methods of sludge treatment, dehydration of sludge, methods of final disposal, production, use and sale of by-products, and costs. The last chapter is devoted to the conclusions and recommendations of the working party.

**Symposium on Dynamic Testing of Soils.** A.S.T.M. Special Technical Publication No. 156. *American Society for Testing Materials, 1916 Race-street, Philadelphia 3, Pennsylvania, U.S.A.* (3·50 dols.)
The 12 papers, with discussions, included in this symposium, are intended to present all available information, and to discuss as yet unsolved problems in the field of soil dynamics. Five papers stress the theoretical approach, while the remaining seven use experimental data to set up a compatible theory. The symposium is international with papers presented by authors from several European countries.

**Electricity Undertakings of the World, 1954-55.** The Electrical Journal Red Book. Sixty-fourth edition. *Benn Brothers, Limited, Bouverie House, 154 Fleet-street, London, E.C.4.* (30*s.*)
In the new edition particular attention has been concentrated on the British Commonwealth and Foreign Undertakings sections, and further information of undertakings in Nova Scotia, Saskatchewan, Malaya, Sarawak and Norway has been included. Details of the latest changes in the organisation of the British Electricity Authority are incorporated up to the latest date possible before going to press.

**Cost Accounting and the Engineer.** By KENNETH B. MITCHELL. Published for "Machine Shop Magazine" by *Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1.* (10*s.* 6*d.*)
This book has been written with the aim of explaining modern costing techniques, and showing how they are applied to the engineer's own department, and to the business as a whole. It is not a textbook on cost accounting and is not intended for specialists. The first part of the book examines in some detail the methods of accounting for materials, labour and overhead expenses; and the second part deals with the subject of budgetary control—the modern system of "forward costing" which has come into being with the advent of scientific management.

**Report on the Derailment which occurred on January 20, 1954, at Thirsk in the North Eastern Region, British Railways,** Ministry of Transport and Civil Aviation, Railway Accidents. *H.M. Stationery Office, Kingsway, London, W.C.2.* (2*s.*)
The conclusion of the Board of Inquiry was that the derailment was due to facing points having been moved irregularly to the mid-position while the express was approaching Thirsk at high speed. As a result of extensive tests it was proved that a false feed had been applied to a point motor when another point machine was energised.

**Light and Lighting: Directory of Manufacturers of Lighting Equipment.** *The Illuminating Engineering Publishing Company, Limited, 32 Victoria-street, London, S.W.1.* (1*s.* 6*d.*)
A directory for buyers of all types of electric lamps, luminaires, accessories and equipment.

**Jane's Fighting Ships, 1954-55.** Edited by RAYMOND V. B. BLACKMAN. *Jane's Fighting Ships Publishing Company, Limited, 25 Gilbert-street, London, W.1.* (84*s.*)
The amount of fresh material in this, the 56th edition, is considerably above the normal. Numerous additions have been made to the technical data and notes, and 535 up-to-date illustrations have been inserted either of new or converted warships, or in replacement of older illustrations. Evidence is found in this issue of the increasing application of the latest scientific and engineering developments to the new warships of the major maritime powers.

# PAST, PRESENT AND FUTURE ELECTRICAL DEVELOPMENT

## SITING AND GAS-WASHING PROBLEMS

In his chairman's address to the Supply Sections of the Institution of Electrical Engineers, delivered on October 27, Mr. J. D. Peattie recalled that 44 years ago Dr. S. Z de Ferranti, in his inaugural address to the Institution, dealt with coal conservation, home-grown food and the better utilisation of labour. He came to the conclusion that the only complete and final solution of these problems was to convert the whole of the coal we used for generating heat and power into electricity and to recover its by-products at a small number of large generating stations. He proposed to convert 60 million tons of coal into an annual output of 131,400 million kilowatt-hours of electricity and to utilise these to supply the whole of the country's varied requirements.

Since that time Mr. Peattie said, great progress had been made in the efficient use of coal, particularly by conversion into electricity. Curiously, however, there had been little change in coal production, although its consumption in statutory generating stations had risen from 3 million tons in 1903 to 37·2 million tons in 1953-54. From the latter amount 63,000 million kilowatt-hours of electricity had been generated.

### CONVERSION PROCESSES

Controversy still raged as to the best chain of conversion processes to satisfy our need for heat. Ferranti pointed out that with electricity, close control of the amount consumed was possible and that it was difficult to waste or use it improperly. There was a wide field for electric process heating in industry to-day and, as the efficiency of generation from low-grade fuels rose and the use of nuclear fuels became significant, conditions would increasingly favour the employment of electricity for this purpose. The electric smelting of iron ore using coke only for chemical reduction was a case in point. Our rise as an iron and steel producing nation had been bound up with the use of hard coking coals. These were, however, in sight of exhaustion and were becoming more and more difficult to extract. Signs were not lacking of a search for radically new processes in manufacture and treatment. It was the opportunity of the electrical industry to offer help in the controlled supply of heat through the medium of electricity on a scale far beyond present practice.

### THE COAL POSITION

The direct use of electricity for chemical processes, particularly in the production of light metals and alloys, had been multiplied many times by the demands of two wars, and we were only on the fringe of further developments in that respect.

There was now a sharp distinction between carbonisation and industrial coal. Reserves of the former were approaching exhaustion and the latter was steadily decreasing in quality. At the same time the proportion of large coal was falling and that of small coal was rising rapidly. Furthermore, the ash content of that small coal was steadily increasing. Coal generally was in short supply and it seemed possible that we were committed indefinitely to import it or other foreign fuels.

Electrical engineers could, however, face the problem with some confidence. The country was now nearly covered with a network of transmission and distribution lines, which connected the generating centres together and to the ultimate consumer. At the generating centres we were once more hoping to gain control after the strain of war and post-war conditions. At the end of July, 1954, the British Electricity Authority had an installed capacity of 19,000 MW in 281 stations, so that Ferranti's prophecy of 25,000 MW in 100 stations was being approached. The average thermal efficiency of generation was 23·54 per cent., which was also in sight of Ferranti's figure of 25 per cent. This would certainly be passed within a year or two. The size of the sets was increasing and 120 MW and 200 MW units were due for installation in 1959 and subsequent years. The average size of the sets in the 1947 programme was 40 MW; in the 1959 programme it would be 85 MW. Similarly, the average boiler capacity, which was 260,000 lb. per hour in 1947, would be 660,000 lb. per hour in 1959.

### FUTURE DIFFICULTIES

While it was well to keep in mind the objective of ever increasing the use of electricity, concern at the difficulties which would have to be faced in attaining that end could not be avoided. Some of these arose from the relations between the supply industry and the community. Two problems were the use of rivers and estuaries as cooling water sources and the discharge of flue gases and dust into the atmosphere. The increasing use of cooling towers could not provide a solution to the restrictions which were being imposed by river boards under their new powers. The result was that sites using rivers were becoming increasingly difficult to find. Suitable coastal sites were more scarce than a glance at the map would suggest.

The problem of atmospheric pollution could be separated into two parts, one concerned with the emission of solid particles and the other with the emission of gases such as sulphur dioxide. With the increasing use of pulverised fuel rapid strides had been made in the efficiency of electrostatic precipitators, which in this country held the field for the extraction of the fine dust from the flue gases. Recent measurements at Little Barford, a station in flat open country, had, in fact, shown that the small residue of dust leaving the chimneys did not settle within two miles of the station in quantities which could be measured with certainty by the standard dust gauges.

### GAS WASHING

So far as sulphur compounds were concerned the costly experiments on flue gas washing at the Battersea, Fulham and Tir John generating stations had led to the conclusion that the best solution of the problem was to discharge the hot unwashed gas from high chimneys into the upper layers of the air, well clear of the buildings, where they dispersed innocuously over wide areas. The proposed use of oil, with its higher sulphur content, as an alternative fuel added to the difficulties. Gas washing had been imposed at Bankside where the boilers were oil-fired. It was debatable whether better results would not have been obtained without it. Nuclear-fuel-fired stations would certainly lead to allied problems in the disposal of radioactive residues. Those difficulties would be overcome as they arose and their nature became better known.

*The Institution of Naval Architects Autumn Meeting (continued from page 592)*

# TESTS ON A LOW-DRAG HYDROFOIL

## THE PERFORMANCE OF LAMINAR-FLOW SECTIONS UNDER MARINE CONDITIONS

The fifth of the six papers presented at the Autumn Meeting of the Institution of Naval Architects at Torquay was read at the morning session on Friday, September 24, by Mr. R. L. Townsin, B.Sc., and dealt with "Experiments with a Low-Drag Hydrofoil." The chair was again taken by Mr. R. B. Shepheard, C.B.E., B.Sc., the Chairman of the Council.

The paper described the main portion of the work undertaken by the author at King's College, University of Durham, during his tenure of the first Froude Research Scholarship. The experimental tests were made in the Ship Division of the National Physical Laboratory. A symmetrical hydrofoil was designed and made, and achieved a boundary layer over 60 per cent. of its surface. The drag of this hydrofoil, with various boundary conditions and at zero angle of incidence, was measured in a towing tank by Pitot traverse, and check drag measurements were made by another method. Streamflow observations were made for all conditions of the hydrofoil. Its drag was calculated at zero incidence for various Reynolds numbers and transition points. The author pointed out that the hydrofoil used could be regarded as a full-scale A-bracket strut, tested at full-scale Reynolds numbers.

### CONTROLLED LAMINAR BOUNDARY LAYER

The experiments showed that it was possible to achieve an extensive controlled laminar boundary layer, and the low drag associated with it, in the water of a towing tank; although the only known previous attempt, in 1942, had failed. The residual disturbance produced by the passage of the hydrofoil through the water had no apparent effect on subsequent runs. Even when deliberate attempts were made to trip the flow, by running in the reverse direction down the tank at high speed and immediately running forward at high speed, the streamflow was not observably different from that obtained with a high-speed run made in the morning, after the water had become still overnight; but care had to be taken to ensure that wave-making did not influence either the drag of the section or the readings of the Pitot comb used to measure the drag. All the drag readings taken with the Pitot comb when the hydrofoil was vertical showed the influence of wave-making, and it could not be said that the Pitot comb gave the true two-dimensional drag coefficient under those conditions. In experiments with trip wires, it was found that a wire only 0·01 in. in diameter would break up the laminar flow at all but the lowest Reynolds numbers; and, once the flow was broken, it could not be made to rejoin the surface as a laminar layer. It appeared impracticable, therefore, to obtain the advantages of low-drag sections and shapes in general ship service, as fouling would rapidly destroy the laminar boundary layer; and even with propellers, normally of much smoother finish than a ship's hull, no excrescences of the order of 0·01 in. could be permitted except near the trailing edge. An investigation was made of a model screw, however, from which it appeared that, for the working condition, low-drag sections would give an efficiency gain of 5 per cent.

### DISCUSSION

Mr. A. Silverleaf opened the discussion, saying that the paper put forward some very positive conclusions. He would like to expand Mr. Townsin's brief reference to the only previous attempt to carry out similar work; it was done by two well-known aerodynamicists in the same tank. Their hope was that, "if the test were successful a valuable technique for the investigation of laminar-flow sections would be established because of the simplicity of drag measurement and of the ease and accuracy with which models can be cut in paraffin wax." They felt that "The William Froude National Tank cannot be used to investigate the properties of laminar-flow aerofoils at high Reynolds numbers unless an experimental technique can be devised for which disturbances due to surface wave and eddy formation do not matter." Mr. Townsin had succeeded where they said that success was not readily achievable, which was a very considerable step. They said that their failure was due largely to early transition caused by wall disturbances; Mr. Townsin had not only succeeded, but had given a true explanation of how they failed.

### HULLS, PROPELLERS AND TORPEDOES

Coming to some of the important practical conclusions from his work: it had shown fairly conclusively that laminar-flow sections were impracticable under ship service conditions. An important consideration was whether laminar-flow hull forms could be devised and used; but the paper did not throw much light on that. So far as propellers were concerned, it reinforced some conclusions which the Ship Division of the N.P.L. had also reached, in the same tank. The work indicated clearly that they could not expect to use laminar-flow sections in propellers for the purpose of improving efficiency; but they could expect to apply them usefully, as was done from other points of view, particularly cavitation delay. Mr. Townsin was a little optimistic in his belief in the lasting quality of the fine finish on the surface of propeller blades after they had been in service for some time; even under the best conditions they developed a roughness which would be in itself sufficient to trip the flow. He would add a further practical conclusion, of which, no doubt, the author was well aware—ships and propellers were not the only bodies which travel through water. Mr. Townsin's conclusions would have a very practical value for those interested in torpedoes.

Mr. H. Lackenby suggested that the author might obtain some information on form effect.

### FROUDE MEDAL PROPOSED

Professor E. V. Telfer proposed the establishment, in the next few years, of a Froude Medal, which would be a continuing and recurring tribute to him; further, in view of the high genius of Froude himself, it should rank with the senior medals throughout the world of science and should be competed for by the best brains in naval architecture throughout the world.

Mr. Townsin's paper was extremely interesting and he agreed with Mr. Silverleaf that it had very practical findings and conclusions; but he felt, where the author had followed the aerodynamic presentation, that he might improve it considerably by realising that the device of the total wetted surface was one which was introduced by Froude himself and which had been developed very much in naval architecture. That changed the picture, because, while naval architects thought in terms of form effect, it was a form effect plus resistance plus unit wetted surface; the form effect included the effect of wetted surface over twice the chord length, and it was important to realise that every piece of wetted surface added to the total resistance of the flow. Again, in an Appendix to the paper he might give a brief outline of Dowlen's method of calculating the resistance; it would add to the value of the paper and would help others by indicating the usefulness of that method.

The next point was in connection with the practicability of laminar flow on ship forms. When very small models were tested, it was found that, whereas very low resistance was observed at some speeds, very often at lower speeds the resistance would shoot up to an enormous figure; that type of laminar separation was due to the inability of the pressure on the outer body to recover. There was no need to have laminar flow throughout the length of the model because it appeared certain that in the after body, where pressure recovery was so important, the laminar flow forbade pressure recovery. It was better, therefore, merely to have laminar flow to a partial extent and to encourage the flow in the after body to be turbulent, to produce the best possible pressure recovery.

Dr. E. C. B. Corlett referred to the author's discussion of the possibility of obtaining laminar flow on brackets, propellers, etc. Prof. Gray, of Cambridge, a biologist, had done some interesting work on fish and found reason to believe that the effective horse-power supplied by fish was far greater than the power output of the muscles. It appeared that the power output from the muscles of any animal was constant. The scales of fish were comparatively rough, and on the top of the scale there was a mucous film, clearly to reduce the roughness coefficient. But, even making allowance for that, it was still hard to reconcile the e.h.p. figure suggested as the possible power output of the fish. Was that not an attempt by Nature to produce laminar flow over a portion of the body? He invited Mr. Townsin's comments on the point, especially as he understood it had puzzled their friends at Haslar.

### SEMI-SUBMERGED FOIL

Commander (E) Peter DuCane, O.B.E., R.N.(ret.) remarked that other speakers had questioned whether or not laminar flow could be obtained on a hydrofoil. That applied, surely, to the sub-surface of a submerged foil? The whole of the pressure recovery would be rather different from that of a foil which broke the surface. It was difficult to know what to call those hydrofoils, aerofoils, etc.

Professor E. V. Telfer recalled a recent paper on the testing of a model in two halves, the one half independently of the other. The after half gave a result that was almost zero. The flow round that part of a ship was squeezing in and propelling the ship forward; it had a better pressure restoration, and the better the pressure restoration that could be given to the after body, the better the result. He thought that was one of the things which gave the fish a perfect pressure-restoration mechanism. Some biologists felt that, from the mouth to the gills of a fish, there was also an element of another propulsive mechanism. The fish tried to swallow and there was a pressure out of the gills in the normal way of feeding, giving a pressure balance which further helped to propel the fish. He did not think a fish really tried to get laminar flow. Nature had provided an entirely different method of providing the fish with propulsion. The salmon could leap; therefore it had a propulsive power of several times its own weight.

### AUTHOR'S REPLY

Mr. Townsin, replying to the discussion, thanked Mr. Silverleaf for having expanded on the previous tests. He preferred not to be drawn by Mr. Lackenby into an immediate discussion of form effect, but he would write something later. With regard to Professor Telfer's remarks, of course a body could not have laminar flow over its whole surface; that would be incredibly difficult to achieve in practice. The talk about fish power was not entirely true. He had asked about the horse-power from the muscles, and obtained some percentages which were astonishing.

*To be continued*

# STRESSES IN SHORT BEAMS

## 1—EXPERIMENTAL ANALYSIS

*By J. S. Caswell**

One of the postulates underlying the simple theory of the strength of beams is that the span-depth ratio is large, but as this condition does not exist in some applications of the theory, the calculated stresses may not then be truly representative of the real stresses in the beam. Moreover, the theory does not include the effects of the local stresses produced at and near the points of application of the loads. Under real conditions, these local stresses are superimposed on the stresses produced by bending and shear, and it is important that maximum values of the resultant stresses shall not exceed assigned safe values. Under conditions of a sustained steady stress, the high local stresses may not have serious consequences in ductile materials because local yielding of the material could occur. But when the loading and any associated motion of the part cause a continuous cyclic change of stress, the maximum values may exceed the appropriate endurance limit of the material and bring about failure by fatigue. These stress conditions arise in steel and cast-iron rolls used for hot and cold rolling of metals, and when the maximum internal stresses are too high, fatigue failure occurs in the form of flaking and spawling of the surface of the rolls, consequent on the high values of the maximum shear stress.

The investigations described in this article have been carried out for the purpose of comparing a theoretical estimate of the maximum shear stresses which occur in short-span simply-supported beams carrying a central load, with an experimental estimate of these stresses obtained by the photo-elastic method of analysis. The work, which has been undertaken in the Engineering Department of the University of Swansea, formed part of a larger research project being conducted on behalf of, and with the assistance of, the Department of Scientific and Industrial Research. The theoretical estimates were made on the basis of the Stokes-Wilson theory†‡ which embraces the total effect of the loading conditions and which is discussed in Part 2, to be published later.

The maximum values of the stresses occur at the mid-section, and the appropriate equations for the longitudinal stress $\sigma_y$ and the transverse stress $\sigma_x$ at a given point on this section are: for the longitudinal stress,

$$\sigma_y = \frac{3\,P}{2\,t\,c^3}\left(\frac{l}{2} - \frac{c}{\pi}\right)(x - c) + \frac{P}{2\,\pi\,c\,t}, \quad (1)$$

and for the transverse stress,

$$\sigma_x = \frac{2\,P}{\pi\,t}\left(\frac{x}{4\,c^3} - \frac{1}{x}\right), \quad (2)$$

where the terms have the meaning shown in Fig. 1, herewith, and the reduced form of the expressions, applying to the particular beams used in this investigation, are: for the longitudinal stress,

$$\sigma_y = P\{(26{\cdot}95\,l - 8{\cdot}04)(x - 0{\cdot}47) + 1{\cdot}26\}, \quad (3)$$

and for the transverse stress,

$$\sigma_x = 2{\cdot}37\,P\left(1{\cdot}13\,x - \frac{1}{x}\right). \quad (4)$$

For the experimental determination of the stresses by photo-elasticity, beams of varying span-depth ratio were cut from annealed transparent Bakelite, BT.61-893, which was supplied in sheets approximately ¼ in. thick.

### EXPERIMENTAL DETAILS

The model beams were 0·268 in. thick by 0·94 in. deep and were of lengths suitable for spans of 5 in., 4 in., 3 in., 2 in., 1·7 in., 1·4 in., and 1 in. Consequently, the span-depth ratios were 5·32, 4·26, 3·19, 2·13, 1·81, 1·48 and 1·06, respectively. An additional beam, 10 in. long and of the same transverse dimensions, was made for the purpose of some preliminary experiments on the effect of span-depth ratio when the beam was subject to a constant bending moment produced by pure bending. The photo-elastic fringe patterns were obtained with a parallel circular polariscope to produce a white background so that the beam supports could be seen in the photographs. Two series of experiments were carried out, namely, series A: to examine the effect of changes in the span-depth ratio when a beam is subjected to a pure bending moment generated by loads applied beyond the supports, so that the beam is unaffected by load-contact stresses at mid-span; and series B: to examine the combined effect of changes in span-depth ratio and the load-contact forces when the same bending moment at mid-span as used for series A is produced by a central load applied directly to the beam. In both series the mid-span sections were the same and the bending moment at mid-span was made the same in every case, namely, 103·8 in.-lb.

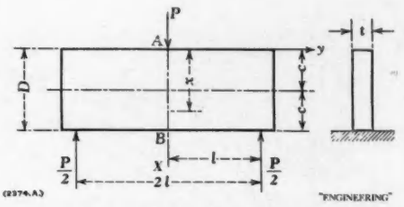



**Fig. 1 Relevant dimensions of the beams used in series B examined in this investigation. The beams have a low span-depth ratio.**

Photographs of the photo-elastic patterns were obtained for all the assigned conditions of loading. Several of these are shown in Fig. 5 and Fig. 6, and are discussed later, but it is interesting to note here that, although the bending moment is the same in every case at the mid-section of the beams, there is a striking contrast between the stress systems produced by pure bending, Fig. 5, and the stress systems produced by bending, shear and the load-contact stresses, shown in Fig. 6. For the 5-in., 4-in., and 3-in. spans in both series, it was not possible to obtain a photograph of the whole of the photo-elastic pattern for each beam, and it was necessary to move the polariscope laterally to obtain supplementary photographs; consequently, each of the illustrations for these beams comprises three photographs pieced together.

### CALCULATED STRESSES IN BEAMS IN SIMPLE BENDING

The greatest stress values occur at the mid-sections of the beams, and both the principal stresses and the maximum shear stresses have been calculated for a number of positions along the whole depth of the mid-sections. The results are shown in Fig. 2, and in Figs. 3 and 4, on page 626, and general consideration of the Stokes-Wilson equations (to be discussed in Part 2) leads to the following deductions regarding the theoretical values of (*a*) the longitudinal stress, $\sigma_y$, (*b*) the transverse stress, $\sigma_x$, and (*c*) the maximum shear stress $\tau$.

*The Longitudinal Stress.*—The theoretical stress variation with depth of beam, and the stress change with variation in span-depth ratio are shown in Fig. 2, herewith, which illustrates the following points. The stress varies in an unsymmetrical linear manner along the depth of the beam for all span-depth ratios and the rate of change of stress with distance from the upper or compression edge is given by

$$\frac{3\,P}{2\,t\,c^3}\left(\frac{l}{2} - \right)\frac{c}{\pi}\ \text{lb. per sq. in per in.} \quad (5)$$

At the lower edge and the upper edge of the beam, in every case, the longitudinal stress is less than the value calculated by the ordinary bending theory. Although the bending moment is the same in all cases, the longitudinal stresses at the upper and lower edges of the beam are unequal in any particular case, and they fall in value as the span-depth ratio is decreased. The maximum longitudinal tensile stress, $\sigma_t$, at the lower edge is, in every case, greater than the maximum longitudinal compressive stress, $\sigma_c$, at the upper edge. The values of these longitudinal stresses are given by the following expressions:

$$\sigma_t = \left(1 - \frac{4\,c}{3\,\pi\,l}\right)\sigma_0\ \text{lb. per sq. in.} \quad (6)$$

$$\sigma_c = \left(1 - \frac{8\,c}{3\,\pi\,l}\right)\sigma_0\ \text{lb. per sq. in.,} \quad (7)$$

where $l$ is half the span, $c$ half the depth of the beam and $\sigma_0$ is the maximum longitudinal stress calculated from the simple theory of bending.

The zero value of the longitudinal stress, i.e., the neutral point, is in every case above the mid-point of the depth of the beam, and its position

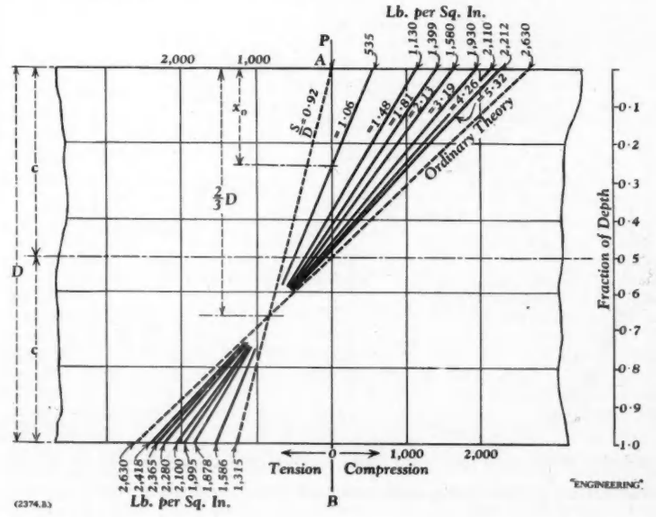



**Fig. 2 Variation of the longitudinal stress $\sigma_y$ at the section A-B with the change in span to depth ratio, $\frac{S}{D}$.**

* Senior Lecturer, Mechanical Engineering, University College of Swansea.

† G. G. Stokes, *Mathematical and Physics Papers*, vol. 5, page 238.

‡ Carus Wilson, "On the Influence of Surface Loading or the Flexure of Beams," *Phil. Mag.*, page 481, vol. 32 (1891).

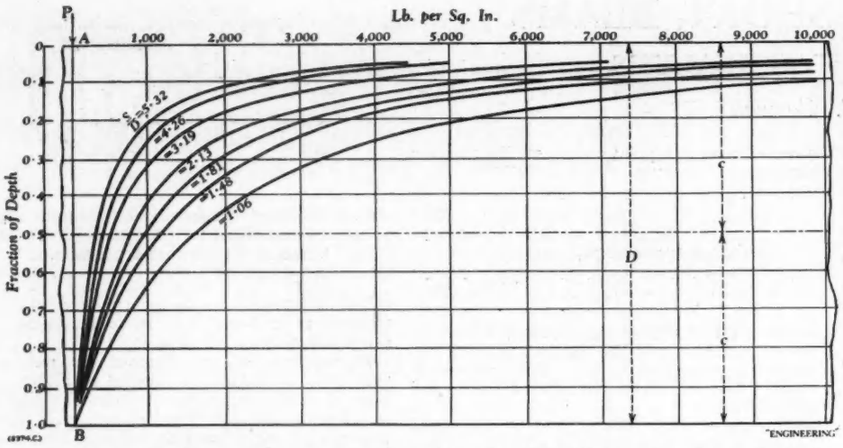



**Fig. 3 Variation of the transverse stress $\sigma_x$ along the section A-B with the change in span to depth ratio, $\frac{S}{D}$.**

rises towards the upper edge as the span-depth ratio is decreased. The depth of the zero stress point below the upper edge is given by the following expression:

$$x_0 = \frac{c}{3}\left(\frac{3\pi l - 8c}{\pi l - 2c}\right) \text{ in.}, \quad . \quad (8)$$

where $l$ and $c$ have the meaning defined above. In every case the longitudinal stress has the same value at a distance of two-thirds of the depth of the beam, measured from the upper edge, and this stress is one-third of the edge stress, $\sigma_0$. The longitudinal compressive stress $\sigma_c$ falls to zero when the span-depth ratio reaches a value of 0·85, and the corresponding tensile stress, $\sigma_t$, at the lower edge, is then equal to half of the edge stress $\sigma_0$.

*The Transverse Stress.*—In order to obtain a graphical representation of the calculated values of the transverse stresses, appropriate values of the thickness $t$, the semi-depth $c$ and the parameter P, have been substituted in the general equation (2) for the transverse stress. The results are shown in Fig. 3, above. The curves have not been plotted for values of $x$ less than 0·05 in. of the depth, because the stress values are related to hypothetical conditions of point or line contact loading not obtained in the experimental work. Although the local conditions at the load-contact point affect the transverse values near the upper edge, they will not affect the stress values at points more remote from the upper edge. This is in accordance with St. Venant's principle which states that equivalent-force systems in the immediate vicinity of the point of loading will not affect the stresses further away from the point of loading. From Fig. 3, it will be seen that near the upper edges of the beams the transverse stresses become large, and tend toward an infinite value as the upper edge is approached. At the lower edge, the transverse stress is zero, and there is only one principal stress, namely, the longitudinal stress. The transverse stress at a given point, distant $x$ from the upper edge, is proportional to the load applied to the beam, and the increase of stress per unit addition of load is:

$$\frac{2}{\pi t}\left(\frac{x}{4c^2} - \frac{1}{x}\right) \text{ lb. per sq. in.} \quad . \quad (9)$$

For a given loading condition, the change of value of the stress is small in the lower half of the beam and large in the upper half, and the rate of change at any distance $x$ over the whole depth of the section is

$$\frac{2P}{\pi t}\left(\frac{1}{4c^2} + \frac{1}{x^2}\right) \frac{\text{lb. per sq. in.}}{\text{in. of depth.}} \quad . \quad . \quad . \quad (10)$$

For a given load, P, the transverse stress is independent of the span of the beam.

*The Maximum Shear Stress.*—The stresses $\sigma_y$ and $\sigma_x$ represent the principal stresses along the mid-sections of the beams, and the maximum shear stress is

$$\left(\frac{\sigma_x - \sigma_y}{2}\right) \text{ lb. per sq. in.}$$

The expressions for $\sigma_x$ and $\sigma_y$ may be substituted in this expression and the general characteristics of the maximum shear stress, illustrated in Fig. 4, are as follow. For all span-depth ratios, the maximum shear stress varies from very large values at the upper edge of the beam to relatively small values at the lower edge, and the minimum values occur at varying depths below the upper edge, according to the magnitude of the span-depth ratio. For any of the beams, the minimum value of the maximum shear stress occurs at a distance $x$ below the upper edge, given by

$$x = \left(\frac{1{\cdot}19}{13{\cdot}48\,l - 5{\cdot}365}\right)^{\frac{1}{2}} \text{ in.} \quad . \quad (11)$$

It will be observed that, as the semi-span, $l$, is diminished, the point of minimum value moves from a position near to the upper edge towards the lower edge and that it reaches the lower edge when the span-depth ratio is 0·915, corresponding to a span of 0·86 in. When the above value of $x$ is substituted in the maximum shear stress equation (to be given in Part 2) a value of the semi-span $l$ may be found for which the maximum shear stress is zero. This value is 1·99 in., corresponding to a span-depth ratio of 4·23. This zero value corresponds to a condition under which the longitudinal and the transverse stresses are equal, i.e., $\sigma_y = \sigma_x$, and this would be represented by a single isotropic point on a photograph of the photo-elastic fringe pattern for such a beam under load.

Substitution of the value $l = 1{\cdot}99$ in. in equation (11) shows that the point of zero maximum shear stress, i.e., the isotropic point marked Q in Fig. 4, would be located at a distance $x = 0{\cdot}236$ in., or 25·5 per cent. of the depth, below the upper edge of the beam. This point is unique for two reasons, namely, that (*a*) for values of $x > 0{\cdot}236$ in., corresponding to span-depth ratios less than 4·23, there are no points of zero maximum shear stress, and therefore no isotropic points; and (*b*), for values of $x < 0{\cdot}236$ in., corresponding to span-depth ratios greater than 4·23, there are two points of zero maximum shear stress, and therefore two isotropic points. For the 5-in. span beam (span-depth ratio 5·32) these points, marked U and V on Fig. 4, are situated at depths of $x = 0{\cdot}12$ in. and $x = 0{\cdot}35$ in., corresponding to 12·8 per cent. and 37·2 per cent. of the whole depth, respectively. The progressive change of position of the minimum value of $\tau$ with change of span-depth ratio, is accompanied by a gradual increase of this minimum value as the span-depth ratio decreases. For the span-depth ratio of 4·23, $\tau = 0$ at 25·5 per cent. of the depth below the upper edge, and for a span-depth ratio of 1·06, $\tau$ has a minimum value of 830 lb. per square inch at 99 per cent. of the depth below the upper edge.

The substitution of two sets of values for the parameters P and $l$ in the maximum shear-stress equation produces two stress functions, $f(x)$ and $\phi(x)$ and, on equating the difference between these two functions to zero, the solution for $x$ shows that a point of intersection of the curves occurs at a point where $x = 0{\cdot}76$ in., i.e., at 80·9 per cent. of the depth. Consequently, at this point in the beam depth, the maximum shear stress has the same value for all span-depth ratios. It shows also that below this point there is a reversal in the change of the maximum shear stress with alteration of the span-depth ratio, that is, the stress decreases with a decrease in the span-depth ratio and with the increase of load.

## THE PHOTO-ELASTIC FRINGE PATTERNS

Within the elastic range of the material used for the beam models, there is a linear relation between the maximum shear stress and the fringe value. It will be seen from Fig. 5 that there is uniform spacing of the fringes for the beams of series A which were subjected to pure bending moments of equal value. Consequently, there is a linear stress variation over the depth

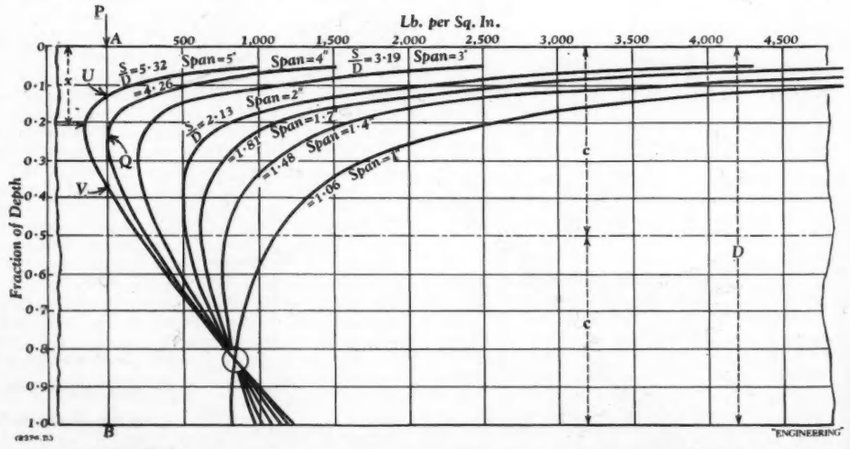
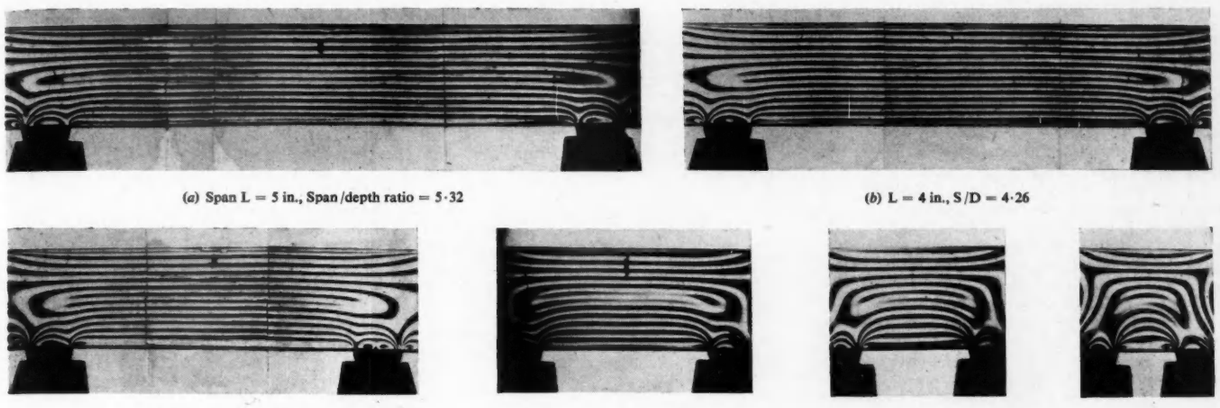


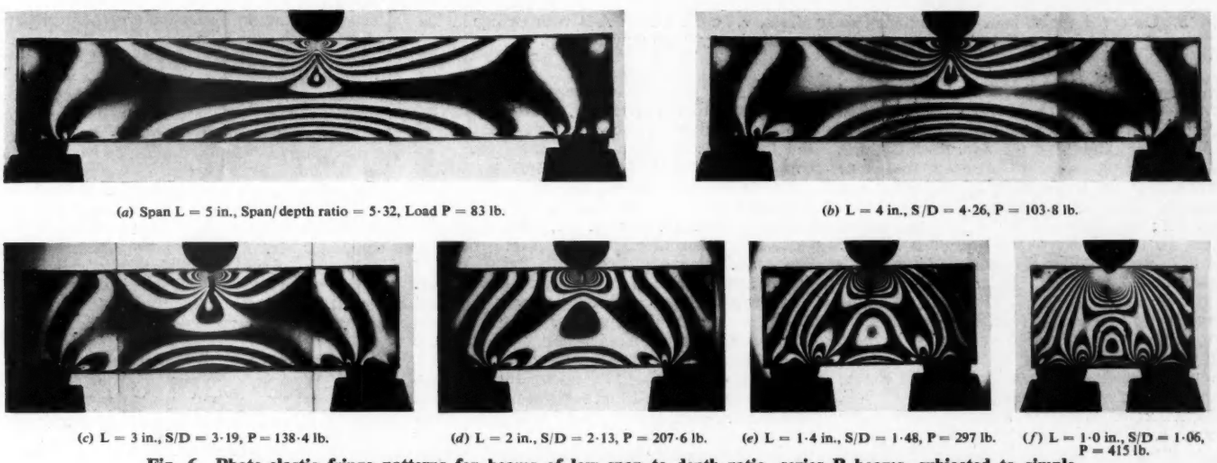

**Fig. 4 Calculated variation of the maximum shear stress $\tau$ along the section A-B with the change in span to depth ratio, $\frac{S}{D}$. The corresponding observed values are shown in Fig. 8.**



(*a*) Span L = 5 in., Span/depth ratio = 5·32 (*b*) L = 4 in., S/D = 4·26

(*c*) L = 3 in., S/D = 3·19 (*d*) L = 2 in., S/D = 2·13 (*e*) L = 1·4 in., S/D = 1·48 (*f*) L = 1·0 in., S/D = 1·06

**Fig. 5 Photo-elastic fringe patterns for pure bending (series A beams) showing the uniform stress conditions at the mid-span.**



(*a*) Span L = 5 in., Span/depth ratio = 5·32, Load P = 83 lb. (*b*) L = 4 in., S/D = 4·26, P = 103·8 lb.

(*c*) L = 3 in., S/D = 3·19, P = 138·4 lb. (*d*) L = 2 in., S/D = 2·13, P = 207·6 lb. (*e*) L = 1·4 in., S/D = 1·48, P = 297 lb. (*f*) L = 1·0 in., S/D = 1·06, P = 415 lb.

**Fig. 6 Photo-elastic fringe patterns for beams of low span to depth ratio, series B beams, subjected to simple bending under a central load P, to produce the same maximum bending moment of 103·8 in.-lb.**

of the beam and it will be observed that, even for the shortest-beam span, the uniform spacing of the fringes at the mid-span section is not much disturbed by the contact forces at the supports. Therefore, under the conditions of loading that obtained for the beams of series A, the fringe patterns indicate that, for all the span-depth ratios considered, the real stresses could be accurately determined by the simple beam theory. It necessarily follows that the fringe value, F, of the material may be used for estimating the stress values from the fringe patterns for the beams of series B. The value of F is given by $F = \frac{\sigma_0}{2n}$ where $\sigma_0$ is the maximum fibre stress calculated from the simple beam theory, and $n$ is the fringe value at the edge of the beam. For a rectangular beam section of thickness $t$ and depth $2c$, subjected to a bending moment M, the maximum fibre stress $\sigma_0 = \frac{6M}{4c^2t}$, and the fringe value $F = \frac{3M}{4c^2tn}$ lb. per sq. in. For M = 103·8 in.-lb., $t$ = 0·268 in., $c$ = 0·47 in. and $n$ = 7, F has the value 188·5 lb. per sq. in.

Under the loading conditions obtaining for series A, the bending moment remains constant up to the points of support. At these points the contact forces superimpose additional stresses on the linear stress system, and the resulting stress conditions approach those which occur in the beams of series B. If the contact forces are small, the stress conditions on the section above a support would correspond closely to those occurring at the mid-section of a centrally loaded long-span beam subjected to the same bending moment and, for these conditions, the simple theory would give satisfactory results. For larger contact forces at the supports and for the same bending moment, there is greater divergence between the values of the real stresses and the calculated stresses, and the general stress conditions are similar to those occurring at the mid-section of the short-span beams loaded as in series B.

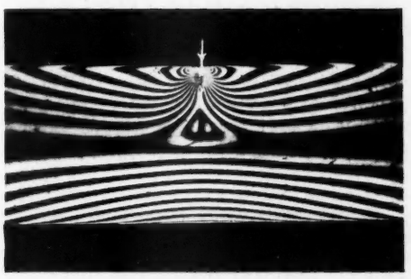


**Fig. 7 Magnified detail of the fringe pattern to show the two isotropic points of the pattern shown in Fig. 6(a). The points are labelled U′ and V′ in Fig. 8. A slightly greater load was applied and a crossed circular polariscope used to give better definition to the upper point.**

The bending moment generated at the mid-sections of the beams of series B remained constant throughout, and equal to that used for the beams of series A, but there are two important differences between the two series in the fringe patterns at the mid-sections, irrespective of the span-depth ratio, namely: (*a*) the distribution of the fringes has now become non-uniform and (*b*), there is a progressive change in the number and the location of the fringes as the span-depth ratio diminishes. These fringe patterns are shown in Figs. 6 (*a*) to (*f*), above, and it will be seen that, with decreasing span, the greater load necessary to maintain a constant bending moment produces stress effects which penetrate more and more deeply into the beam.

*The Point of Minimum* $\tau$.—At the mid-sections of the beams it will be seen from Fig. 6 that the point of minimum fringe value moves progressively towards the lower edge of the beam as the span-depth ratio decreases. This point is easily recognised by its island form, and it will also be observed that the fringe value of the point gradually increases with decreasing value of the span-depth ratio. In the beams with spans less than 4 in., these points are sources or sinks of fringes according to whether the applied load is increased or decreased respectively.

In the case of the 4-in. span beam, the fringe value of this point is zero, and here, therefore, the principal stresses have equal values, the point being an isotropic point which is both single and unique. The gradual increase in the minimum fringe value below this point, as the span-depth ratio diminishes, suggests that a gradual change of value should also occur above the point. Such a condition would require the occurrence of two isotropic points as the span-depth ratio is increased and these points would then be located where the fringe value curve crosses and re-crosses the line of zero $\tau$. These points are not evident in the fringe pattern for the 5-in. span beam shown in Fig. 6 (*a*), but the existence of these points is indicated by the calculated values represented by the maximum

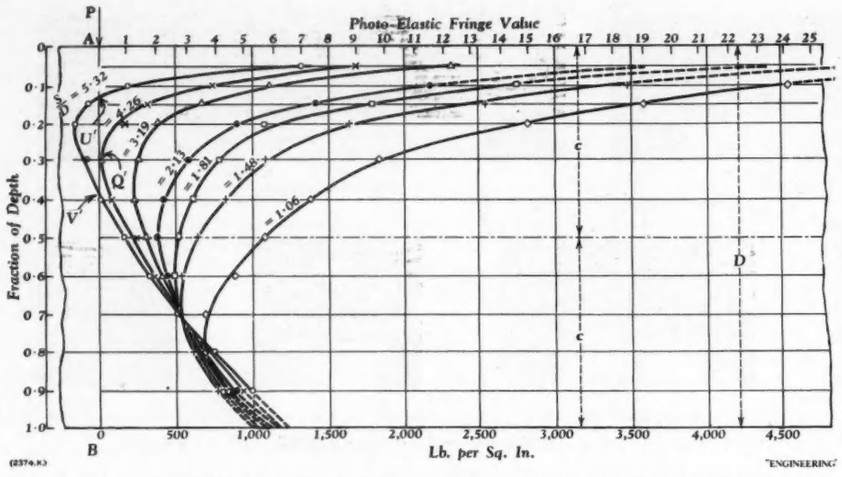



**Fig. 8 Observed variation of the maximum shear stress, $\tau$, at the section A-B with change in the span-depth ratio. The corresponding theoretical curves are shown in Fig. 4.**

shear-stress curve for this particular beam and represented by the points U and V in Fig. 4. In order to show that these points are also present in the fringe pattern for the 5-in. span beam, a photograph of a magnified image of the fringe pattern near the upper edge of the beam was obtained. This is reproduced in Fig. 7, on page 627; the distances of the isotropic points below the upper edge of the beam are 0·12 in. and 0·37 in., these figures closely agreeing with the calculated positions, 0·12 in. and 0·35 in., to be derived in Part 2, equation 25. The downward movement of the point of minimum fringe value is accompanied by a sharp increase in the number of fringes above the point. Below the point the number slowly decreases as the span-depth ratio is decreased.

*Experimental Values of the Maximum Shear Stress, $\tau$.*—The characteristics of the fringe-value curves are shown in Fig. 8, herewith. As may be expected, the greatest values occur at the upper edges of the beams, where the stresses closely approach, and probably exceed, the yield stress of the material. It is not possible to trace the fringe pattern all the way to the point of contact, and accurate fringe-value readings could not be made below one-tenth of the depth of the section for the beams with spans of 3 in. or less. Fringe-value readings at the lower edge are also a little uncertain because slight edge stresses are present and, therefore, below 0·9 of the depth, the curves have been extended only as dotted lines to the lower edge. It appears that the fringe values at the edge vary from 5·2 to 6·4 fringes as the span-depth ratio is increased over the range of the tests. At the edge there is only one principal stress, and the fringe values indicate that the longitudinal stress varies from 1,960 to 2,400 lb. per sq. in., compared with calculated values of 1,586 to 2,418 lb. per square inch., and also compared with 2,630 lb. per square inch obtained by the simple beam theory. The curve for the shortest span beam does not conform with the other curves, but this may be due to the proportionately greater effect of the much larger forces on a beam with so short a span. There is also the possibility that the greater frictional resistance between the beam and the supports has some effect on the fringe pattern and the bunching up of the curves near the lower edges may be due to this resistance.

Towards the lower edges of the beams the fringe value curves converge to a common point corresponding to about three fringes at 0·71 of the depth, compared with a similar point in Fig. 4 having a calculated value of 4·2 fringes at 82 per cent. of the depth. At this latter depth, the observed fringe values vary from 3·5 to 4·4 as the span-depth ratio is increased.

**The second and concluding part of this article will be published in a subsequent issue.**

# PUBLIC HEALTH ENGINEERING

## I.C.E. PRESIDENTIAL ADDRESS

The problems confronting the civil engineer in general, and the public health engineer in particular, were the subject of Mr. David Watson's presidential address to the Institution of Civil Engineers on Tuesday, November 2. The new President began by briefly referring to the lives and work of the founders and early members of the Institution, and quoting at some length from the inaugural address of the third President, Sir John Rennie, who had defined the profession of civil engineering and the contributions it could make to society.

That this contribution was not deservedly recognised, however, was Mr. Watson's next theme and, he commented, "he (the civil engineer) is too modest and does not seek recognition of the essential part he plays in inspiring, planning, and working out all the practical details which eventually give place to the actual direction of the great sources of power in Nature to the use and convenience of man . . . There is still need for clear thinking to abolish all foolish assumption of modesty, untimely silence, and cloistered indifference."

### ALL-IN BIDS

Briefly outlining the development of the present working partnership between consulting engineer and contractor that exists to-day in the United Kingdom, Mr. Watson proceeded to a defence of the system, and to criticise the alternative practice of contractors making "all-in bids" on design as well as on construction. Such a practice quickly led to all the serious evils of competitive design. Too many public authorities were also introducing into the administration of contracts other officials in addition to engineers. That was deplorable, and could only harm by destroying the confidence that now existed between the two sides of the profession, introducing uncertainties, delaying settlements and eventually raising costs.

From these more general observations the President turned to the more specialised sphere in which he himself had practised—public-health engineering. Though this branch of engineering could be said to date back some 200 years, it was not until Edwin Chadwick (1800-1890) that a substantial weight of opinion began to demand the removal of sewage matter from towns, and the use of public money spread over a period of time to pay for the sewers. Early proceedings of the Institution contained many references to papers and ensuing discussions on the practices and merits of the different methods of conveyance and treatment of sewage. For example, the water-carriage of sewage was by no means readily accepted by engineers as the proper method of removal of sewage from dwellings; the proceedings recorded long drawn-out discussions when this principle was challenged and keenly debated.

Despite the growth of technical knowledge in the intervening years, however, too little was as yet known about the cost of sewage purification, and it was a serious reproach to us that, in a country where the abstraction of potable water from, and the discharge of sewage to, our rivers was of ever-growing importance, we should lack basic information about the cost of purification of one of the main discharges to the rivers.

It was not generally known that the real difficulties of sewage purification were due to discharge of liquid wastes from trade premises; many trade wastes, if discharged in too great concentrations, proving inhibitory to biological purification of ordinary domestic sewage. Many of the difficulties were increased by local authorities having both to foster industry and to drain the whole town; by so doing, the result was a sewage difficult to purify. New legislation, concluded Mr. Watson, was long overdue; future legislation should be designed to provide new standards of purification which would pay full regard to the value of the watercourse as a source of public water supply.

★ ★ ★

# PROTECTING BELT CONVEYORS AGAINST DAMAGE

Two protective devices have been designed by Mr. J. A. Wood, electrical engineer at the Ackton Hall Colliery of the National Coal Board, to prevent damage caused by the fouling of the line stands of underground conveyors and by the tearing of the belt itself.

To overcome damage to the line stands two insulated conductors are run the full length of the conveyor and are clamped to each stand under the top belt. These conductors are connected to a relay with two pairs of contacts. One of these pairs is in the control circuit of the driving motor and the other in the circuit of an indicating lamp. Should a line stand be moved or twisted one or both conductors will break, thus causing the motor to be shut down and the lamp to be extinguished. On a long run the conductors may be sectionalised and each section may be connected to a separate relay so that the approximate position of the fault is indicated.

Protection against belt damage is afforded by a rectangular iron framework, which is mounted between two uprights so that it can swing, the uprights themselves being clamped to a girder beneath the delivery drum of the conveyor. Two small rollers, which are maintained in contact with the underside of the belt by a balance weight, are fixed to one end of the framework. Two rods are secured one to each side of the framework and each is connected to the operating lever of a pull key on the uprights. The contacts in this pull key, which are normally closed, are connected in series with a relay in the control circuit of the driving motor. If, however, a belt is broken or its tension released the weighted end of the framework will fall and operate one of the keys. Similarly, if the belt leaves it supporting ropes and sags, the framework will lift and operate the other key. In both cases the supply to the motor will be cut off and a warning bell sounded.

Fig. 1 General view of the Loch Luichart dam during construction from the downstream side.

# CONON VALLEY HYDRO-ELECTRIC SCHEME

## PROGRESS OF A 100-MW SCOTTISH DEVELOPMENT

The development of the resources of the River Conon and its tributaries in Ross-shire, now being undertaken by the North of Scotland Hydro-Electric Board for the generation of electricity, will eventually involve the construction of a number of dams, tunnels and aqueducts, as well as the building of six generating stations with an aggregate installed capacity of 107 MW and an estimated annual output of 440 million kWh. The scheme, a map of which is given in Fig. 2, is being carried out in three stages, the consulting civil engineers being Sir Alexander Gibb and Partners, Queen Anne's Lodge, London S.W.1. The consulting engineers for the generating plant are Merz and McLellan, Carliol House, Newcastle-upon-Tyne, Kennedy and Donkin, Caxton-street, London, S.W.1, acting in a similar capacity for the transmission system, while Shearer and Annand, Dunfermline, and Sir Alexander Gibb and Partners are the architects.

The first stage of this development is sited 20 miles west of Dingwall and utilises the waters of Loch Fannich, which are led through a tunnel to a 24-MW station at Grudie Bridge alongside the confluence of the Rivers Grudie and Bran. This station began operation in 1950 and the associated works have already been fully described in ENGINEERING.* A contract has, however, now been let for raising the level of the loch by constructing a dam, 2,180 ft. long and 35 ft. high, across the outlet of the River Grudie. This dam is to be of the rock-fill type with a concrete facing and will incorporate a concrete spillway section. In addition, a concrete pipe aqueduct has been built from Allt Dearg and another aqueduct from Strath Chrombuill is approaching completion. These will provide about one-quarter of the water flowing into the Fannich reservoir. A further contribution will be obtained through the Moine Beag aqueduct. All these aqueducts have interception weirs constructed at intervals along their length for the collection of water from the numerous small tributaries in the area.

### SECOND-STAGE WORK

The second stage of the development, which is known as the Glascarnoch-Luichart-Torr Achilty scheme, will make use of water from a catchment area of 345 square miles, the average annual rainfall in which is about 75 in., and this will permit a yearly production of some 290 million kWh. It will involve the construction of power stations at Glascarnoch (24 MW), Achanalt (2 MW), Luichart (24 MW), and Torr Achilty (15 MW), the positions of which are also shown in Fig. 2. At the present time the works at Luichart are nearly completed and the station is running, while the rest of the scheme is in various stages of construction.

A reservoir is also being formed in Strath Vaich by constructing an earth-fill dam 600 ft. long and 80 ft. high, work on which is still in its early stages. This reservoir will receive water through a tunnel from Glen Beag and through aqueducts from Loch Crom, Strath Rannoch and the western slopes of Ben Wyvis. Construction of these works, however, has not begun. The Strath Vaich reservoir will also be connected by a tunnel of D section, 2 miles long and 9 ft. wide, to the Glascarnoch reservoir. This tunnel has already been driven and lining is now proceeding.

The Glascarnoch reservoir will be formed by building a composite concrete and earth-fill dam across the existing valley. This dam, which is still in the early stages of construction, will be 1,670 ft. long and 97 ft. high. The reservoir will be connected to Loch Luichart by a D-section tunnel, 4½ miles long and 10 ft. wide, which is also under construction, and to which the Allt Choire Mhuilidh will be connected. Water from outlying streams will be picked up by the Loch Droma aqueduct. Before being discharged into Loch Luichart the water will pass through the Glascarnoch power station. As will be seen from Fig. 2, fish hecks have been built in the neighbourhood of these works to prevent salmon from being trapped behind the Glascarnoch and Vaich dams.

A dam is being built across the River Meig, near Curin, to divert water into Loch Luichart. This dam is of the composite gravity and earth-fill type and is 540 ft. long and 70 ft. high. The reservoir thus formed will be connected to Loch Luichart by a D-section tunnel which is 8,617 ft. long and 12 ft. 9 in. wide. Both these works are almost completed.

Loch Luichart receives the tail-race water from the Grudie Bridge power station and will also obtain the discharge from the future Achanalt power station. This station will, in turn, be fed from a barrage and intake weir, which is under construction at the outlet of Loch a Chuilinn to regulate the flow of the River Bran.

### FUTURE DEVELOPMENTS

After leaving the Loch Luichart station, the

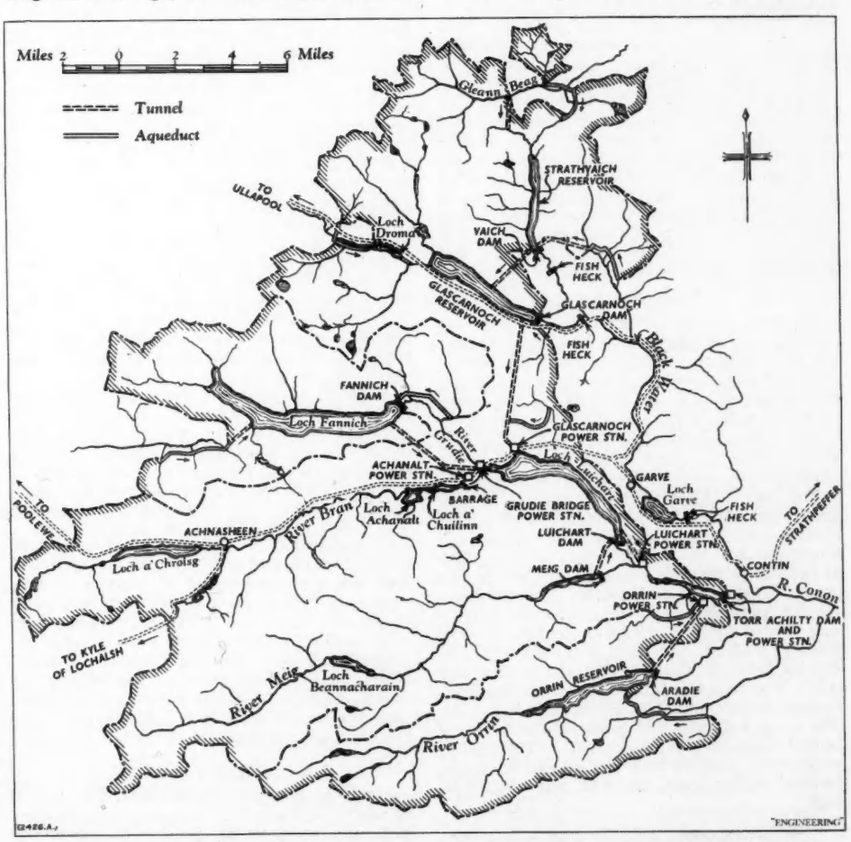



Fig. 2 Map of Conon Valley area showing work completed, in progress and projected.

* See ENGINEERING, vol. 172, pages 65 *et seq.*, (1951).

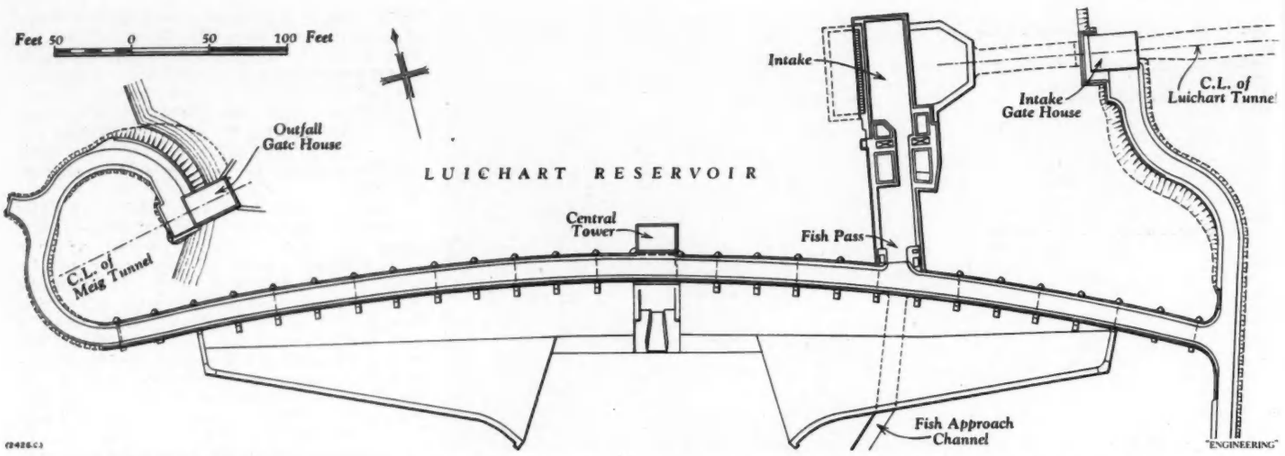



**Fig. 3 Plan showing arrangement of Loch Luichart dam, including Loch Meig tunnel outlet, intake to power station and fish pass.**

works in connection with which are described in detail below, the water will flow down the River Conon to a dam at Torr Achilty. This dam, which is of the gravity type and is 700 ft. long by 50 ft. high, is rapidly nearing completion. The power station, which has been incorporated in it, is also almost ready, and one of the 7·5 MW sets should be running by the end of this year. The function of this dam is to regulate the flow of water downstream in much the same way as does the Pitlochry dam of the Tummel-Garry scheme.* It incorporates a fish pass, which works on the same principle as a canal lock, the water rising in a shaft and thus carrying the fish to the level of the reservoir.

The Orrin scheme, which forms the third section of this important project, has only recently been approved. Its position is, however, shown in Fig. 2. The works will consist of a concrete gravity dam, 970 ft. long and 120 ft. high, which will be built across the River Orrin at Aradie. The reservoir thus formed will also be fed through the Allt Goibhre aqueduct and water will be led from it through a D-shaped tunnel, 8 ft. 6 in. wide and 3¼ miles long, to a power station near Ackonokie, the installed capacity of which will be 18 MW and the estimated annual output 74 million kWh. This tunnel will also receive water through the Allt na Fainich aqueduct, which will be connected to it a short distance above the power station. The water leaving the power station will be discharged into the Torr Achilty reservoir and re-utilised in the Torr Achilty station.

## LUICHART DAM

The Luichart dam, the contractors for the construction of which were Reed and Mallik, Limited, Milford Manor, Salisbury, is of straightforward gravity section and is laid on a flat curve with a radius of 1,518 ft. 6 in. Its layout is shown in the plan reproduced in Fig. 3, while a section through the central tower is given in Fig. 4. Fig 1 is a general view taken from the downstream side during construction.

The dam is 715 ft. 6 in. long, and 66 ft. high above the mid-point foundation level. It is divided into 26 bays of which the two at each abutment are of non-spillway section. One at the centre contains the main and emergency ground sluice gates and another accommodates the fish pass shafts, the remainder being spillway sections. The effective length of the spillway is 483 ft., the width of the side channels varying from 16 ft. to 73 ft. on the downstream side. The main bays are 48 ft. long on the front face and are separated by a closer gap 5 ft. wide. The sluice and main and emergency gates in the central tower are in separate shafts. These gates, which were supplied by Glenfield and Kennedy, Limited, Kilmarnock, are 8 ft. wide by 10 ft. high.

* See ENGINEERING, vol 170, page 425 *et seq.*, (1950)

The spillways are provided with training walls which are 5 ft. high and are surmounted by pre-cast concrete cope blocks. The left-hand spillway, below part of which is the fish approach channel, is illuminated by three Lenscrete lights.

## CONSTRUCTIONAL DETAILS

Work on the dam was begun in January, 1951, and, as the site was quite inaccessible, a new road, about ½ mile in length, had first to be constructed through the solid rock and an existing track widened and re-laid for about the same distance. Loch Luichart was already being used to supply water to a small power station, which formed an earlier hydro-electric development, and for that purpose its level had been raised by a weir at the south end. The height and section of this weir was increased by concrete additions to form the upstream cofferdams for the new work. The right half of the dam was constructed first, the stream being temporarily diverted to the left-hand channel, which was widened and graded to increase the flow to 4,000 cusecs. The right-hand side of this channel was sealed by concrete training walls and steel sheet piling, which were tied to islands both above and below the site.

Excavation was begun in August, 1951, and was almost entirely in solid rock there being very little soft over-burden which was mainly hard-packed gravel. The rock was principally micaschist incorporating veinous quartz and presented no operational difficulties. The shot holes were drilled with 49 lb. wet-type sinker drills, which were operated by compressed air, tungsten-carbide tipped single chisel steels of British and Swedish manufacture being used. Gelignol, which was fired electrically, was employed as an explosive, the consumption being slightly less than ½ lb. per cubic yard.

Broken rock from the faces was tipped into trays, which were lifted by five electrically-operated derricks and unloaded into side-tipping skips. Trains of these skips, which had a capacity of two cubic yards, were hauled by Diesel locomotives to dumping grounds, a total of 33,600 cubic yards being dealt with in this way. The main trench was finished with a 1 in 12 cross-fall down to the cut-off, which was from 5 to 8 ft. deep and 3 ft. wide. The cut-off itself was pressure-grouted at intervals of 5 ft. over the length of the dam in 10 ft. and 20 ft. stages and down to 91 ft. into rock. Test holes were drilled along it on a heavy rake, but generally the rock was tight and the quantity of grout injected was small. Deep drilling was carried out with 50 lb. sinker drills using coupled rods, a water swivel and tungsten-carbide four-point bits 2 in. in diameter.

## CONCRETE MIXING

It was specified that rich dense concrete should be used where contact was made with the base rock and to form an impervious membrane 18 in. thick on the front and back faces of the dam. The hearting concrete was less rich and 2½ in. aggregate, consisting of gravel from the neighbouring river beds, was employed.

The concrete-mixing plant was designed and built by Reed and Mallik, Limited, and was sited so that the incoming aggregates could be unloaded directly into the main hoppers. These hoppers, below which was a travelling weighbar, contained the sand and the four grades of aggregate used, and provided a reserve of 165 tons. Emergency storage was provided in addition. Cement was transported in bags on pallets, which were carried in small hand-operated lift trucks, and mixing was effected in one ¾ cubic yard and one 1 cubic yard closed-drum mixers.

The hearting concrete was unloaded from the mixer drums into two cubic yard drop-bottom skips, while that for the facings was discharged into a second series of skips of special design. These skips were hauled on flat steel bogies by Diesel locomotives and were lifted by derricks so that their contents could be deposited inside the shuttering. The quality of the concrete was investigated regularly by syphon-can tests so as to control the water/cement ratio. The test-cube results, after 28 days, were usually about 5,800 lb. per square inch for the facing concrete and 3,860 lb. per square inch for the hearting.

## SHUTTERING DESIGN

All the shuttering was of high-grade Douglas fir, the joints being grooved and slip-tongued. It was made up in panels 11 ft. long and equipped with " soldiers " of steel channel. In shuttering the bays provision was made for vertical key-ways in the closer gap faces and each 4 ft. pour was formed with two 12-in. steps with large keyways between them. All the concrete was compacted with compressed-air vibrators of the poker type, the total amount placed being rather more than 50,000 cubic yards. In order to allow adequate cooling and shrinkage, concrete was not placed in the closer gaps until at least six weeks after it had been poured in the adjacent bays. In some cases, the concrete for these gaps was pumped and provision was also made for subsequent grouting by forming ducts in the upstream face on each side. Test holes were drilled to a maximum depth of 143 ft. through the heart of the dam, but, as in the case of the cut-off, little or no grout could be injected.

On completion of the right half of the dam, the water was diverted through two temporary openings, 15 ft. wide and 10 ft. high, tapering to the back face, and the cofferdams were re-erected so that the left half could be constructed in the manner already described. Use was also made of the ground sluice when the water rose above a certain level. Subsequently, these openings were plugged in four operations after the sealing gates had been dropped. A copper seal was inserted in the soffit of each opening and a system of perforated pipes and " no fines " concrete blocks were installed for

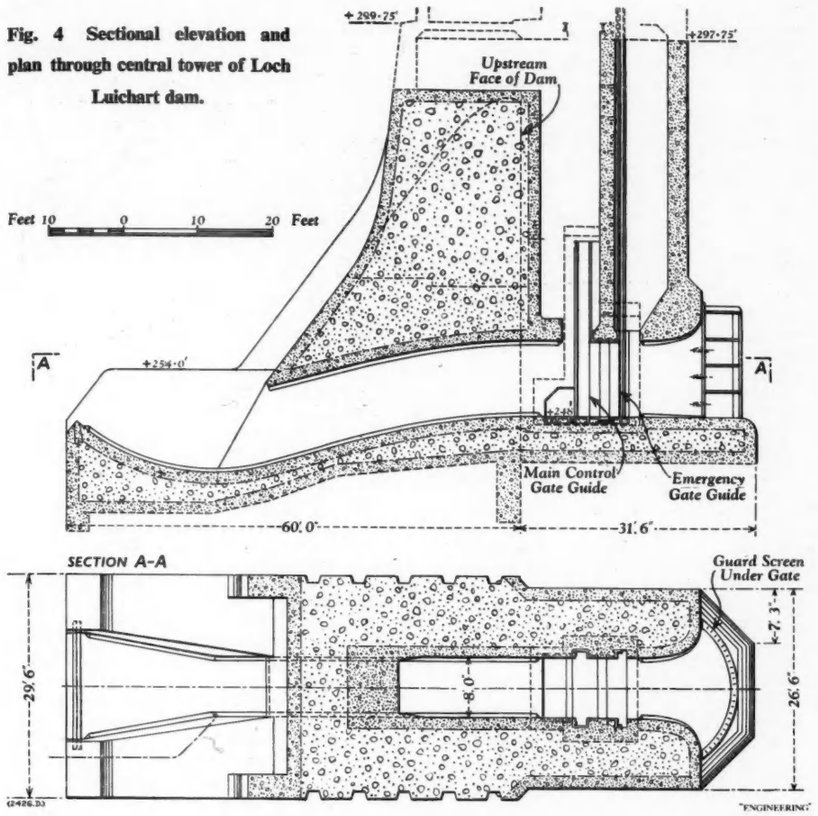



**Fig. 4 Sectional elevation and plan through central tower of Loch Luichart dam.**

grouting purposes. The gates themselves were of baulk timber, these sealing arrangements proving entirely satisfactory.

The spillway bucket was cast as a separate operation after the dam pours had risen above a certain level and the spillway slab was in position. For this purpose a heavy box-out shutter was clamped to the surface of the main shutters at the required inclination, thus forming a deep check which ensured that the bucket "pour" was of considerable mass.

## SPILLWAY BRIDGE

The spillway bridge is of interest since it is the first time that a pre-stressed structure has been used for this purpose. As a result, there has been a considerable saving in material; only 51 per cent. of the concrete and 42·8 per cent. of the steel have been used, compared with what would have been necessary for the normal reinforced-concrete bridge originally specified. There have also been economies in shuttering and labour.

As will be seen from Fig. 3, the bridge consists of 26 ft. 6 in. spans, one end being fixed. Each span is made up of six beams, which are 10 in. deep and 2 ft. 3½ in. wide. They were cast on the site on concrete beds and the cubes therefrom were required to develop a strength of 5,500 lb. per square inch after 28 days. Longitudinal stress was applied by Macalloy bars, ducts for which were formed by means of Ductube while casting was in progress. Three bars were used, the one in the centre being 1 in. and the other two ⅞ in. in diameter. These bars pass through pre-cast end anchor blocks, which were reinforced with a 1½ in. by 4 in. by 20 in. steel distribution plate. Initial stressing was effected by keys to enable the beams to be removed from the bed and the final stresses of 79,000 lb. and 60,000 lb. were obtained by jacking the bars to an extension of 1 $\frac{1}{16}$ in. After setting, the joints between the beams were grouted with well-rammed cement mortar, and twelve 0·2 in. Freysinnet wire cables were passed through the transverse ducts. Five cables were used on each span, the wire extension being 1 $\frac{1}{16}$ in. under a load of 68,000 lb. The deflection of a span carrying an 8-ton road roller was found to be less than $\frac{1}{16}$ in.

The bridge was completed by a bituminous macadam carpet, which is sealed with bituminous dust, a pre-cast concrete parapet and curb, containing the cable ducts, and a tubular balustrade. The pre-stressed work was carried out in collaboration with Mr. E. W. H. Gifford.

## FISH LADDER

As in many other of the North of Scotland Hydro-Electric Board's schemes considerable weight has been given to the demands of the fishing interests. Hitherto salmon did not proceed above the foot of the Conon Falls, but with a view to extending the spawning areas they are now to be encouraged to run up to the head waters of the river feeding Loch Luichart. To achieve this change, the Conon Falls are being made passable and, after clearing the lochs of pike and perch, stocking of the upper reaches has taken place.

To enable the fish to negotiate the dam, a Borland type fish pass has been constructed as shown in Fig. 3 and in more detail in Fig. 5. This pass, which is said to be the largest of its kind yet built, consists essentially of a pair of inclined culverts, each of which is 12 ft. wide and 6 ft. deep. These culverts are connected to chambers at the top of the upstream face and the bottom of the downstream face of the dam. At the commencement of the cycle of operations a sluice gate at the entrance to the lower chamber is opened so that the water contained in the culvert and upper chamber is discharged. The fish are thereafter encouraged to enter the lower chamber from downstream, being assisted in their movement by a channel built well out into the stream, as shown in Fig. 3. The lower gate is then closed so that the lower chamber and shaft gradually fill with water from above the dam, the result being that the fish are able to swim into the upper chamber. The gate remains open throughout the cycle and is automatically adjusted to suit the varying level of the loch. Arrangements are made for maintaining a small flow when the bottom gate is closed so as to encourage the imprisoned fish to ascend or descend and to provide cover for them. The flow in the downstream approach channel can also be increased when necessary.

As regards the construction of this pass, part of the approach channel and of the lower chambers are under the dam, while most of the inclined culverts and the upper chambers project from the upstream face and are connected to the tunnel intake. The work of constructing the pass had to be carried out at high speed and presented many difficulties owing to the complexity of its shape and the heavy reinforcement necessary. As a result of working to a close schedule and pouring the concrete in 8 ft. and 10 ft. lifts it was, however, completed from the foundation to the first stage impounding level in two months.

The fish pass incorporates a space in which a small generating set is installed. This consists of a turbine, which is operated by water drawn from the loch itself and drives a Bruce Peebles induction generator with an output of 85 kW at 415 volt when running at 765 r.p.m. This set has been installed to make use of the compensation water which it is obligatory to supply and the power from which would otherwise be wasted.

## MEIG TUNNEL

As shown in Fig. 2, the water of the Meig reservoir, which as already mentioned, has been formed by building a composite gravity and earth-fill dam 540 ft. long and 70 ft. high, is diverted into Loch Luichart through a tunnel. This tunnel, which is of D-section and is 12 ft. 9 in. wide and 8,617 ft. long, was, except for 500 ft. at the outfall end, driven by George Wimpey and Company, Limited, Hammersmith-grove, London, W.6. In carrying out this work the rock encountered was mainly mica schist, which was drilled both from the floor level and from a gantry using air legs. Wet sinker 49-lb. drills with tungsten-carbide single-chisel tipped steels were employed. By carefully setting and drilling the holes for each round, the explosive used was reduced to 2·7 lb. per cubic yard and the overbreak was kept down to a low figure. The footage was raised from 280 ft. to 640 ft. as the training of the crews improved.

Mucking was effected by rocker shovels, which loaded the spoil into cars. These cars were run on rails which moved forward with the face and were hauled out by Diesel locomotives

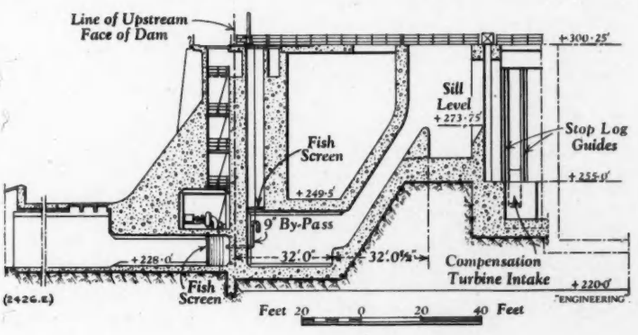



**Fig. 5 Arrangement of fish pass at Loch Luichart dam.**

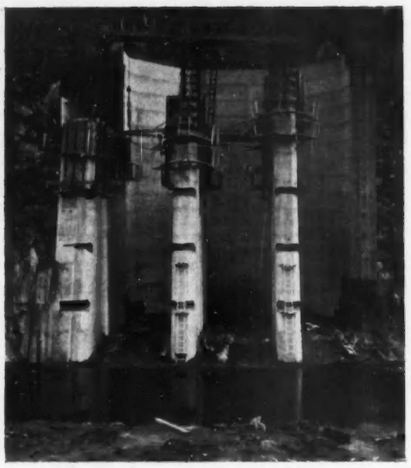


**Fig. 6 General view of Loch Luichart intake under construction.**

equipped with smoke boxes. Air-driven fans connected to portable trunking were used for ventilation.

In this section of the tunnel, the lining was placed in a travelling shutter using a Pressweld placer. The last 500 ft. of the tunnel and the outfall work were constructed by Reed and Mallik, and in this section the concrete was supplied by a 6-in. pump. Subsequently, the crown was pressure-grouted through holes at 20 ft. centres and the lining was painted with bituminous paint to protect it from the acid in the peaty water. There are reinforced-concrete gate houses at both the inlet and outlet of the tunnel, the former containing a control and the latter a stop gate.

## LOCH LUICHART TUNNEL

As will be seen from Fig. 3 the intake from Loch Luichart to the tunnel leading to the power station is combined with the upper part of the fish pass. The design of this part of the works, for which George Wimpey and Company, were also the contractors, was governed by the fishery requirements. These necessitated the provision of an entrance 50 ft. wide and 50 ft. high to reduce the velocity of the flow and thus prevent small fish from being held against the screens. In addition to the trash racks, which have a clear opening of 5½ in. between the bars and are equipped with mechanical rakes, a second set of screens has been installed to prevent the smolt from entering the tunnel. These screens, which are placed downstream of the trash rack cover the whole area of the intake and are arranged in panels each of which measures 15 ft. 1 in. by 11 ft. 3 in. They are lifted by a grappling beam and gantry. Fig. 6 shows the intake under construction.

The intake structure is connected by a length of tunnel to a gate shaft, which has been built a short distance upstream from the dam. This shaft, which is a circular structure about 80 ft. deep, contains both emergency and control gates, the function of the former, which measures 12 ft. by 18 ft., being to shut off the water so that the well can be emptied and the control gate inspected. It will generally be maintained in the raised position and is electrically operated. The control gate, which is of the free-roller type, measures 12 ft. by 18 ft. and is of the same design as that at Loch Sloy*, It is operated by an electrically-driven winch at the top of the control tower. Both these gates and control gear were supplied by Glenfield and Kennedy, Limited, Kilmarnock, and include trips whereby they can be closed automatically in an emergency.

The intake and fish pass were constructed inside a cofferdam which consisted partly of a concrete wall attached to the dam and partly of a steel pile bulkhead which was supported by rock fill.

After passing through the intake gates the water enters a short transition section, about 30 ft. long, which merges into the tunnel proper. This tunnel, which is about 4,300 ft. long, is of D-section, the floor being 16 ft. wide and being laid on a slope of 1 in 20 falling from the sides to the centre. The vertical walls are 8 ft. high and are surmounted by an arched portion with a radius of 8 ft. The tunnel is laid on a gradient of 1 in 135, and, where the rock is of suitable strength, is lined with concrete to a minimum thickness of 6 in. Steel-arch supports were, however, used over a short length where the geological conditions made strengthening necessary. These supports consist of 8 in. by 5 in. rolled-steel frames which are placed at centres not exceeding 5 ft. and are covered with concrete to a minimum depth of 6 in. Corrugated mild-steel sheeting was placed behind the supports.

## CONSTRUCTIONAL ARRANGEMENTS

The tunnel was driven from an adit approximately 10 ft. square. This was situated near the portal and rose on a gradient of 1 in 100 to a point between two bends. As the tunnel itself is on a gradient pumping was unnecessary.

Swedish drilling machines and steels were employed for boring, the former consisting of high-speed equipment mounted on an air-leg and capable of operation by one man. Hexagonal ⅞ in. steels with tungsten-carbide tips and a chisel bit were employed, the lengths varying from 2 ft. 7½ in. to 10 ft. 6 in. A full face of 17 ft. allowing for the 6-in. concrete lining, was excavated for which purpose a timber-decked staging, mounted on wheels and running on a 15-ft. gauge track with longitudinal sleepers, was used. A burn cut was employed and proved satisfactory in the spongy micaceous schist, a drilling rate of 6 in. per minute being maintained.

The explosive used was Polar Ammon gelignite, which was fired by a 100-shot exploder, the face being subsequently cleaned by compressed air. The spoil was unloaded into skips by Eimco rocker shovels, which were moved from one track to another in a compressed-air operated cage, and were subsequently hauled away by Diesel locomotives. The average weekly rate of advance was 82 ft.

On completion of the driving, the invert was cleared and the rock washed with compressed air on both sides of a central 2-ft. gauge track. A concrete sub-base was then formed to a definite level and rails laid on a 7 ft. gauge to carry two gantries.

## CONCRETE LINING

Concrete for lining was obtained from two 1 cubic yard mixers at the entrance to the adit which unloaded into two 2 cubic yard wet hoppers. It was taken into the tunnel in trains of two mixers, each holding three 24-cubic feet batches. The formwork consisted of a travelling steel structure which ran on 70 lb. rails at 7 ft. centres, and into which the concrete was shot by a Pressweld placer through a 6-in. pipe in the crown of the shutter. A 6-in. nib was formed at the toes of the tunnel sides for screeding the finished invert. Access to the concrete for punning and vibration was obtained through side doors. The speed of placing depended upon how quickly the Pressweld could be filled, but an average of 40 batches an hour was frequently obtained. A drag screed, which could be drawn forward by a compressed-air winch or by a monkey winch, was used to form the finished invert. After an interval of four weeks, holes were drilled through the tunnel arch at 10 ft. centres and grout was injected to fill the voids.

Some 400 ft. from the tunnel portal is a circular surge shaft, 65 ft. 6 in. in diameter, the height of which, from the invert to the parapet, is 126 ft. This shaft was driven both from the ground surface and from the tunnel. At the surface there was about 30 ft. of overburden in which berms were roughly formed by a bulldozer, leaving about 14 ft. of boulder clay to be excavated. Simultaneously, a 12 ft. by 6 ft. stope was driven upwards from the tunnel; and the remainder of the excavated material was thrown down the hole and loaded into skips by a rocker shovel. When a sound bed of rock was reached round the perimeter, a concrete garland was cast round the shaft, the internal diameter of which was 2 ft. greater than that of the finished lining.

The sliding form employed for lining the shaft consisted of a buttress girder faced with timber, which was suspended by 26 steel reinforcing rods. These rods, which were 1 in. in diameter, were attached to screw jacks, the latter being carried in a double channel cantilevered out from the garland. The concrete was brought into the tunnel and tipped into skips, which were lifted by a 7-ton derrick at the top of the shaft. Their contents were then tipped into a hopper from which the concrete was removed in barrows and placed round the perimeter in thin layers. After placing, the concrete was lightly punned and the horizontal reinforcing bars were ties to two rows of vertical bars.

When the concrete had been in position for just over four hours the raising of the form was commenced and continued without stopping until the garland was reached. Thereafter, the form work rose on the jacks instead of the suspension rods. A 3 ft. reinforced concrete retaining wall was produced in this way, while above it an 8 ft. high parapet wall 18 in. thick was built by reducing the diameter of the back shutter.

The constructional plant was pneumatically operated from three stationary compressors, each of which had an output of 800 cub. ft. per minute. The water supply was obtained from a 10,000-gallon tank, which was built high on the hillside to provide the necessary head and was fed either by gravity or, during dry weather, from the River Conon.

## TUNNEL LINING

The tunnel is lined with ⅝-in. steel plates for a distance of 240 ft. upstream from the portal, thus forming the pipe shown in Fig. 7. This pipe is connected to the penstock by a portion 24 ft. long, which tapers from 17 ft. to 16 ft. The lining was dispatched from the works of P. and W. MacLellan, Limited, Glasgow, as semi-circular plates 8 ft. long, which were assembled in a revolving welding jig outside the tunnel into sections 16 ft. long and 17 ft. in diameter, there being four plates to a section. Double-V butt-welding, using the down-hand method, was then carried out and four flanged rollers mounted on brackets were attached to each section. This enabled the completed assembly to be hauled into the tunnel on rails laid at 6 ft. centres on the first stage of the invert concrete.

The circumferential joints between the sections were then single-V welded from the inside on to external backing straps. When this operation had been completed concrete was pumped into the space between the rock and the lining, the latter being strutted at the top to prevent flotation. The lining is connected to the penstock by a make-up piece.

## PENSTOCK DESIGN

The penstock, which was also constructed by P. and W. MacLellan, Limited, consists of a steel pipe 38 ft. 6 in. long and 16 ft. in diameter. and connects the tunnel lining to a bifurcation. This bifurcation is constructed of two conical sections tapering in diameter from 16 ft. to 11 ft. in a distance of 58 ft. The two 11-ft. pipes continue for a distance of 15 ft. 6 in. to a bend and then run downhill for about 106 ft. before tapering down to a diameter of 10 ft. After passing through a vertical bend, the two 10-ft. pipes continue horizontally for 15 ft. before reaching the turbine inlet valves.

The penstock itself is made up of ¾-in. plates and is entirely of welded construction. The strakes are generally 8 ft. long and consist of two plates joined by longitudinal double-V butt welds. These welds were made down-hand in revolving manipulators, those for the 16-ft. pipes on the site and the others in the workshops,

* See ENGINEERING, vol. 170, page 25 (1950).

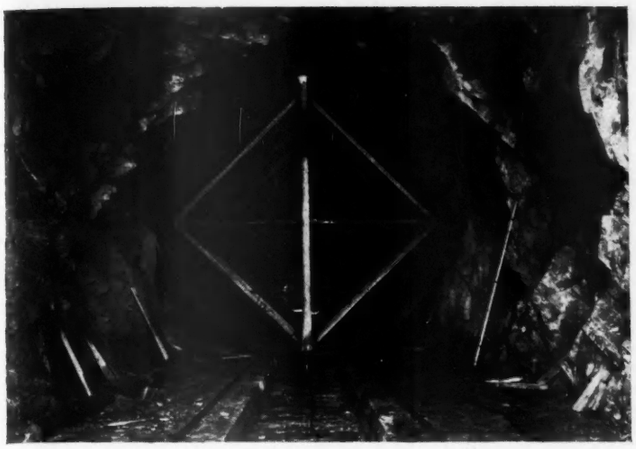


Fig. 7 Steel lining at tunnel portal.

the latter being stress-relieved before dispatch. The strakes were assembled by a crane sited near the bifurcation, although some of the down-stream sections were hauled into position on steel skids and were welded together circumferentially by a single-V butt weld.

The penstock is carried on steel pedestals, which rest on concrete foundations at 24 ft. centres. There is no provision for expansion, as it is laid in trenches cut in the hillside and covered with a concrete slab 9 in. thick, over which soil is laid. After completion, it was sealed by a steel bulkhead at the upstream end and by the two turbine valves at the down-stream end, filled with water and subjected to a hydraulic pressure of 136 lb. per square inch at the down-stream end for nine hours.

## GENERATING PLANT AND REGULATING MECHANISM

The generating plant in the Loch Luichart power station, for which Merz and McLellan were the consulting engineers, consists of two 12-MW vertical-shaft alternators driven by Francis turbines, which were manufactured at the Scotstoun works of Harland and Wolff, Limited, for the English Electric Company, Limited, Kingsway, London, W.C.2, and are designed to operate at a net head of 160 ft. and a speed of 250 r.p.m., the maximum gross head being 185 ft.

The main turbine-inlet valves, which are of the butterfly type, are 10 ft. in diameter and were manufactured at the Clydebank works of John Brown and Company (Clydebank), Limited, for Boving and Company, Limited, Kingsway, London, W.C.2.

The spiral casings of the turbines, which are substantially circular in cross section and of logarithmic-spiral form, consists of mild-steel plates. The casing plates are butt-welded to a central cast-steel speed ring which incorporates streamlined stay vanes. These vanes form a bridge between the upper and lower parts of the unit and guide the water into the gate apparatus. Owing to transport limitations, the casings were delivered to the site in halves, where they were welded together and, after being hydraulically tested, were buried in concrete in order to ensure solidity.

The mild-steel generator-support barrels are bolted to the speed rings and are surrounded by reinforced-concrete blocks which are integral with the upstream wall of the station, thus giving rigid construction. The top flanges carry the thrust bearings and extensions to these barrels carry the alternator stator. The turbine runners consist of single steel castings with streamlined outlet edges. The vanes have been designed so as to ensure a long life and their exits are protected by a coating of stainless steel. The torque is transmitted from the runners to the shafts by a bedded-in transverse key. The top covers are of fabricated construction. They are bolted to the speed ring and carry the housing of the turbine bearing.

The regulating mechanism, through which the water passes to the runner of each turbine, consists primarily of steel swivel gates which are cast integral with their stems. These stems rotate in gunmetal bushes, water leakage being prevented by rubber rings. The swivel gates are operated by a mild-steel regulating ring to which they are connected by levers and links of the off-set type. These links are of cast iron and are designed so that, in the event of an obstruction becoming lodged between two gates, a link will break some time before an excessive force can be exerted on any part of the guide apparatus.

The regulating ring is supported on the turbine cover and slides on lubricated bronze pads so that it can centre itself and thus balance the forces exerted on it by the two connecting rods from the governor servo-motor. This servo-motor and the governor actuator are supplied with oil from an air/oil receiver which is kept charged by a pump.

The turbine speed is controlled by a pendulum governor, which is driven from the main shaft and regulates the pressure of the oil supplied to a servo-motor. The mechanism incorporates a safety device which closes the gates in event of the speed of the set dropping to 30 per cent. below normal or if the governor drive fails. There is also an overspeed device, which operates when the speed exceeds the normal value by 25 per cent., and closes the gates. At the same time the main valve is closed by energising a solenoid, which operates a pilot valve controlling a hydraulic servo-motor. There is also a relief valve which opens should the governor close suddenly and discharges the water through a branch on the spiral casing opposite the inlet into the tail race.

The draught tube is fabricated from mild-steel plates and consists of an upper taper pipe and bend. After assembly, the tubes were buried in concrete to secure a solid foundation while, in order to prevent excessive vacuum or shock due to the rupture of the water column when the load is suddenly removed, air is admitted to the draught tube through a snifting valve on the upper turbine cover and balancing holes in the crown of the runner.

The alternators, which have an output of 12 MW at 11 kV, are of the totally-enclosed umbrella type with one guide bearing and a thrust bearing, which is located below the rotor. These bearings are of the pivoted-pad type and are immersed in the same oil bath, with an external oil-circulating system consisting of a tank, motor-driven pump and cooler. The turbine bearing is of the plain journal type with a circulating-oil system, the reservoir of which is an integral part of the bearing assembly.

## ALTERNATOR DESIGN

The stator frame of the alternator is of fabricated steel and divided into two sections, the core being built of annealed soft-iron laminations containing a little silicon. The stator winding is of the basket type, the coils being held in position in open slots by impregnated hardwood wedges. The rotor is of built-up construction with fans at each end, ventilation being on the closed-circuit principle. The necessary cooling water is supplied from the pipe line, through strainers, to a ring main round the top of the generator pedestals. Electric heaters are fitted inside the alternator casings to keep the temperature above dewpoint when the set is standing idle. Arrangements have also been made to allow part of the hot air from the alternator ventilating system to be diverted into the turbine room for warming the station.

The main and pilot exciters are direct-coupled to the alternator and are totally enclosed. All the necessary remote-control apparatus and protective devices are provided and there are a standby turbine-driven governor oil pump and standby direct-current motor-driven lubricating pumps, so that starting can be carried out when no external source of power is available.

## SWITCHGEAR AND TRANSFORMERS

The alternators are connected to the 11-kV bus-bars through 800-ampere circuit-breakers and thence through 1,600-ampere circuit-breakers to two 25-MVA 11/132-kV transformers of Bruce Peebles manufacture; and on to the 132-kV lines. One main transformer is capable of dealing with the output from both machines. The switchgear, which was supplied by A. Reyrolle and Company, Limited, Hebburn, Co. Durham, is of metal-clad construction. It comprises horizontal draw-out solenoid-operated circuit-breakers with a rupturing capacity of 500 MVA. Remote control is effected from panels and sheet-steel cubicles in an operating room. These cubicles embody a diagram of the main connections as well as telephone-type central alarm equipment and hydraulic indicators. Current for operating the switchgear and for the alarm circuits is obtained from a lead-acid battery.

The essential auxiliaries of each machine are supplied from a 50-kVA, 11/0·433-kV transformer, of Bruce Peebles manufacture, and is connected to the alternator terminals. The non-essential auxiliaries are supplied from a common services board of Reyrolle manufacture, which is connected to earthing transformers on the low-tension side of the main transformers, as well as to a 33/0·433-kV transformer, the high-tension side of which is connected to the local 33-kV mains. The arrangement is similar to that at Grudie Bridge, which has already been described in ENGINEERING.*

## SEQUENTIAL/PARALLEL OPERATION

The sequential/parallel system has been adopted for automatic control. In this the slowest operations in starting the turbine, that is flushing the bearings from the stand-by lubricating pumps, raising the governor oil pressure and opening the turbine inlet valves, form a first stage and are carried out in parallel thus minimising the overall time taken for starting. The turbine guide vanes are then opened and the machine is run up to speed. The normal lubricating and governor oil pumps run up as unit auxiliaries as the speed of the turbine increases and take over automatically from the stand-by pumps. The final stage of the sequence includes proof of delivery from the normal pumps and the operation of a voltage regulator energised by the pilot exciter when the alternator has developed full voltage. At this stage, a signal is transmitted to the control room that the machine is ready to be synchronised. At present this operation is effected locally, but supervision will eventually be carried out from a load dispatching centre at Torr Achilty. If, however, any failure occurs during the starting period the set will be automatically shut down and an alarm given in the operating room. The output of the station is transmitted at 132 kV by two overhead steel-cored aluminium lines to a substation at Beauly.

* See ENGINEERING vol. 172, page 131 (1951).

# THE PUBLIC WORKS CONGRESS AND EXHIBITION

## CIVIL ENGINEERING PLANT AT OLYMPIA

This year's Public Works and Municipal Services Congress and Exhibition will be opened next Monday, November 15, by the Minister of Works, Mr. Nigel Birch, M.P., and will remain open until Saturday, November 20. On each weekday a number of papers will be presented for discussion on a variety of subjects of particular interest to county and borough engineers and surveyors. In the exhibition about 270 firms will be displaying machines, equipment and apparatus or will be illustrating and demonstrating the processes and methods which they handle. In this and succeeding reports we give brief descriptions of some of the exhibits, particularly those of recent introduction.

### SOIL-STABILISATION PLANT

This is the first occasion on which Rotary Hoes, Limited, Horndon, have taken part in the Public Works Exhibition and they will have on display their Platypus crawler tractors and the very successful Howard soil-stabilisation plant. The Howard trench-digger and pipe-layer is being exhibited on the stand of Mobile Power (London), Limited, of Enfield, Middlesex.

The single-pass soil-stabilisation plant, illustrated in Fig. 1, consists of the leading tractor which hauls the combined cement spreader, mixer and pulveriser (this unit also embodies the water-spray) and the third unit, the compactor, is an independent self-powered machine. A very full description of this equipment was given in our issue of January 8, earlier this year, but the importance of soil stabilisation in modern road construction cannot be over emphasised, and this equipment of Rotary Hoes is the only British-made plant for this work that is yet available. At a single pass the equipment is able to process a soil formation 6 ft. wide by 8 in. deep at a speed of between 2 ft. and 10 ft. per minute depending on the type of soil.

The capacity of the cement hopper is six bags of cement (670 lb.) and the discharge can be varied over a wide range from 3 per cent. to 20 per cent. of the volume of the soil being treated. The third machine of the unit consists of a final distributor and mixing rotor which trowels the soil/cement backwards towards the compactors, which are six 5-cwt. cast-iron blocks. Driving power for the rotor and the compactor is obtained from the 48-h.p. Perkins Diesel engine on the machine.

### " TRACTO-SHOVEL "

Among the tractors and compressors to be displayed on the stand of Mackay Industrial Equipment, Limited, Feltham, Middlesex, is a new machine to this country—the Allis Chalmers HD9G, shown in Fig. 2. It is a larger version of the now well-known HD5G " Tracto-shovels."

The tractor is fitted with a General Motors four-cylinder two-stroke Diesel engine giving a maximum brake horse-power of 84, and 72 h.p. at the drawbar at an engine speed of 1,600 r.p.m. There are six forward speeds and three in reverse; the bottom gear gives a drawbar pull of 19,030 lb. at a speed of 1·4 m.p.h., the top gear raises the speed to 5·7 m.p.h. and the highest speed in reverse is 4·4 m.p.h. The combined clutch and brake steering which, for ease of operation, is power-assisted gives the tractor a turning radius of 14 ft. 7½ in. With the standard 16-in. semi-grouser tracks the ground pressure is 9·71 lb. per square inch or 1,400 lb. per square foot.

In order to carry the front-mounted equipment the HD9G has been built with an extra long track (an additional roller has been employed to support the track) and a longer truck frame.

The " Tractomotive " equipment is operated by a hydraulic pump mounted at the front of the engine and controlled by a four-position control valve (raise, hold, lower and float) conveniently located close to the driver's right hand. Both the lift cylinders and the dump cylinders are double acting, so giving a down pressure for excavating, a controlled " dump " and a quick return. The full loading cycle, from stockpile to lorry and back to stockpile, takes 44 seconds. The full-width bucket has a heaped capacity of 2½ cub. yd. and a struck capacity of 2 cub. yd.; the maximum discharge height is 9 ft. 1 in.

### FREE-PISTON AIR COMPRESSOR

Also displayed on Mackay's stand will be the Pescara-Muntz P42H air compressor, a free-piston engine in which the work done by opposed Diesel pistons operating on a two-stroke cycle is converted directly into compressed air, thus eliminating the complicated double conversion of reciprocating motion to rotary motion and vice versa which takes place in conventional compressors. The trolley-mounted unit to be displayed is illustrated in Fig. 3.

Each Diesel piston is bolted to a piston rod. The outer end of one rod is attached to the cushion piston, and the outer end of the second rod to the compressor piston. The cushion piston operates in a closed cylinder and provides the return energy for the next stroke. Air is delivered to the air receiver from the outer face of the compressor piston and the inner face sucks in scavenge air. This scavenge air enters the Diesel cylinder from a reservoir and assists in the expulsion of the exhaust gases which in turn are used to drive the cooling fan, the water pump and a lubricating-oil pump which supplies a metered supply of oil to the compressor cylinder only. The action of the two groups of pistons is synchronised by connecting links attached to rocking levers, one of which carries a double-sided cam which operates both the fuel-injection pump and the lubricating pump which force feeds all the bearings.

The P42H is readily started in all weather conditions down to −18 deg. C. by a powerful spring which throws the Diesel pistons together at full working speed. The output of compressed air is controlled by a regulator which is sensitive to fluctuations in delivery air pressure and varies the stroke of the pistons by altering the quantity of fuel injected. This gives a continuous adjustment of output and results in an almost constant air pressure at the tools. Since the two groups of pistons are equal in weight and opposite in motion there is no vibration and a coin can be balanced on edge on the machine while it is running. The output is 105 cub. ft. of free air per minute at a maximum operating pressure of 100 lb. per square inch. Two complete sets of tools and hoses can be locked up under the canopy of the compressor, which is mounted on a chassis of which the air receivers form the main longitudinal members.

### 7½-CUB. YD. DUMPER

Of the extensive range of road-making, building and civil-engineering contractors' plant made by Aveling-Barford, Limited, Grantham, space on the stand will only allow seven machines to be exhibited. They include two machines which have been seen before at earlier Public Works Exhibitions, the 99-H Grader and the Calfdozer (both of which were described in our report of the previous Exhibition in 1952). Machines which are new at this exhibition but have been seen elsewhere are a tandem roller, a maintenance grader and 3-cub. yd. dumper. Entirely new and being shown for the first time at any exhibition are a light roller and a 7½-cub. yd. dumper.

The dumper, which is illustrated in Fig. 4, opposite, carries a payload of 20,000 lb. at what the makers believe to be a higher all-round speed than is accomplished by any other dumper of comparable size. This has been attained by fitting a higher engine power for gross laden weight than is employed in any other dumper. The engine is a Leyland six-cylinder Diesel developing 150 brake horse-power at 2,200 r.p.m. for an all-up loaded weight of 40,320 lb. Fully loaded, the dumper can climb a gradient of one in four.

As on other dumpers made by the company, two-way steering has been adopted, making use of a single steering wheel and duplicated foot controls which allow the driver always to face the direction of travel and yet retain normal steering action; the machine can thus be driven with equal facility in either the forward or reverse direction. An automotive type of gearbox in conjunction with a simple forward/reverse box gives four speeds in both directions, the top speed being 21·8 m.p.h. Heavy-duty cam-operated brakes incorporating Clayton Dewandre boosting cylinders for the air pressure have been fitted to all four wheels.

The body and frame have been built up by welding from rolled steel sections and plate; as may be seen from the illustration, the driver's cab is protected by a steel canopy built on the dumper body. Tipping is by twin hydraulic two-stage telescopic rams which also lower the body under power. The maximum tipping angle of 70 deg. is reached in 16 seconds and the body can be arrested and held in any position below the upper limit. Electric lighting fittings, and a totally-enclosed steel cab with safety-glass windows giving full protection to the driver against the weather, have been fitted.

### LIGHT-WEIGHT ROLLER

The new Aveling-Barford roller, type GF, shown in Fig. 5, opposite, is built in two sizes having unballasted weights of 2¼ and 3¼ tons. It is driven by a two-cylinder vertical water-cooled Diesel engine which, driving through a constant-mesh gearbox, gives the machine two speeds—2·0 and 4·12 m.p.h.—in both forward and reverse directions. The final drive is by worm and wheel, the unit incorporating a differential gear which can be locked from the driving seat.

A short wheelbase of only 6 ft. 7½ in. makes the roller very manœuvrable but the danger of a marked road surface has been lessened by the 5-in. wide overlap that the rear rolls have on each side of the front roll. Both the front and the rear rolls are of steel plates and are designed for water ballasting; adjustable scrapers have also been fitted and, as may be seen from the illustration, a water tank of 30 gallons capacity has been provided, with sprinkler attachments above each roller.

Steering is effected through double-reduction bevel gears and a quadrant plate. The Girling internal-expanding brakes fitted to the rear rolls can be operated by either foot or hand and can be locked when parking.

### PNEUMATIC DRILL

Portable compressors with a free-air capacity of between 60 cub. ft. and 500 cub. ft. per minute delivered at pressures up to 100 lb. per square inch are to be shown on the stand of Broom and Wade, Limited, High Wycombe, Buckinghamshire. Other portable machines will include a spray-painting unit having a compressor displacement of 20 cub. ft. of free air per minute, delivered at between 20 lb. and 80 lb. per square inch, and driven by a 5-h.p. petrol engine. Examples of a new range of lightweight stationary compressors, with twin cylinders and air cooled, are also to be shown.

The pneumatic tools on the stand will include that illustrated in Fig. 6, opposite, a new concrete breaker, type RB770, which is a long-stroke tool designed to be suitable for the heaviest duty with low fatigue to the operator. Maintenance work on the drill has been simplified by keeping the number of component parts as low as possible. The principal details are as follows: the bore is 2½ in. and the stroke 7 in.; the overall length (without the steel) is 26½ in.; the weight (also without the steel) is 74 lb.; and the number of blows delivered is 1,050 per minute.

*To be continued*

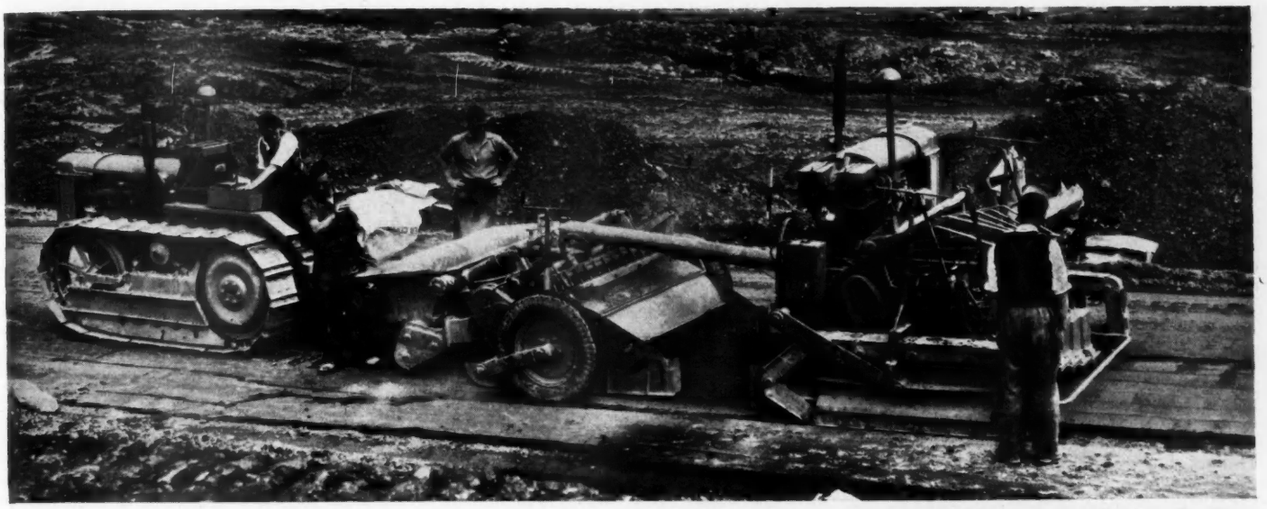


Fig. 1 Soil stabilisation has become widespread in recent years for the construction of estate roads and for strengthening the sub-grade for more important trunk roads and airfield runways. The Howard " single-pass " equipment, illustrated here, has several advantages, placing and mixing the cement and then compacting the soil-cement mix during one traverse.

Fig. 2 The Allis-Chalmers " Tracto-shovel " shown here has a maximum drawbar pull of over 19,000 lb. and a struck shovel capacity of 2 cub. yd. The maximum discharge height is 9 ft. 1 in. and the loading cycle takes 44 sec.

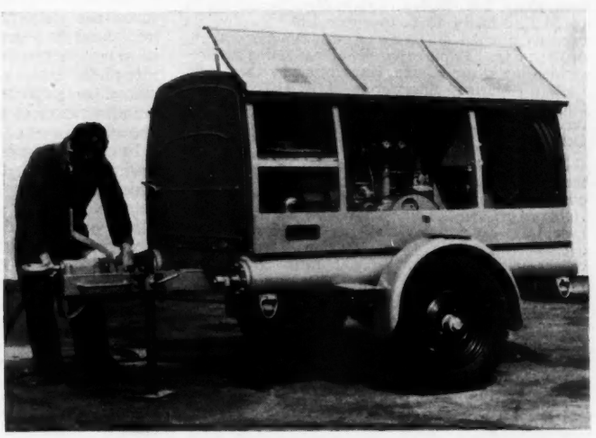


Fig. 3 In the Pescara-Munz free-piston air compressor, the air is compressed directly by a two-stroke cycle. The capacity is 105 cub. ft. of free air per min. delivered at 100 lb. per sq. inch.

Fig. 4 With a pay-load of 20,000 lb. and a 150 b.h.p. six-cylinder Diesel engine, the Aveling-Barford 7½-cub. yd. dumper has four speeds which can be used with equal facility in both directions as the driver can face either way.

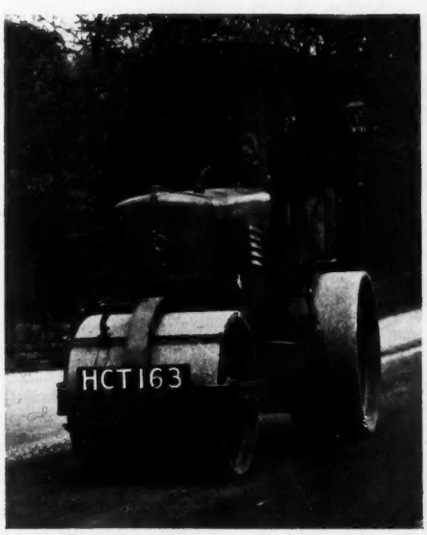



Fig. 5 The extra width of rear rolls over the front roll reduces the likelihood of surface marks being made by the new Aveling-Barford light-weight roller.

Fig. 6 The new Broom-Wade concrete breaker has been simplified by having fewer parts.

## LAUNCHES AND TRIAL TRIPS

M.S. "FOUNTAINS ABBEY."—Single-screw cargo vessel, built by Hall, Russell & Co., Ltd., Aberdeen, for Associated Humber Lines, Hull. Second of two sister ships. Main dimensions: 256 ft. overall by 38 ft. 6 in. by 21 ft. 6 in. to shelter deck; deadweight capacity, about 1,240 tons on a draught of 13 ft. 5 in. Kincaid-Polar marine Diesel engine, developing 2,100 b.h.p. at 220 r.p.m., constructed by John G. Kincaid & Co., Ltd., Greenock, and installed by the shipbuilders. Trial trip, October 12.

M.S. "VASSIJAURE."—Single-screw oil tanker, built and engined by the Götaverken Shipyard, Gothenburg, Sweden, for Trafik AB Grängesberg-Oxelösund, Stockholm, Sweden. Main dimensions: 596 ft. overall by 74 ft. 6 in. by 44 ft. 3 in.; deadweight capacity, about 21,500 tons on a draught of 31 ft. Götaverken nine-cylinder single-acting two-stroke Diesel engine, developing 6,750 b.h.p. at 112 r.p.m. Speed, 14½ knots, fully loaded. Launch, October 12.

M.S. "FILBY QUEEN."—Single-screw trawler, built by John Lewis & Sons, Ltd., Aberdeen, for Talisman Trawlers, Limited, Lowestoft. Third vessel of a series of four for these owners. Main dimensions: 100 ft. between perpendiculars by 20 ft. by 10 ft. 9 in. Six-cylinder Diesel engine developing 440 b.h.p. at 300 r.p.m., constructed by Crossley Brothers Ltd., Openshaw, Manchester 11. Launch, October 12.

S.S. "BALLYLAGAN."—Single-screw cargo vessel, built by Austin and Pickersgill Ltd., Sunderland, for John Kelly, Ltd., Belfast. Main dimensions: 224 ft. by 34 ft. 3 in. by 15 ft. to upper deck; deadweight capacity, about 1,385 tons on a mean summer draught of 14 ft. 6 in. Triple-expansion direct-acting surface-condensing steam engine, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Steam supplied by one marine oil-burning boiler. Service speed, 9½ knots. Launch, October 12.

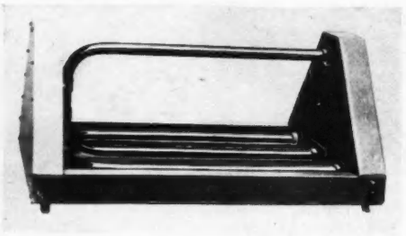
M.S. "ATHELMERE."—Single-screw oil tanker for the bulk carriage of molasses, oil or spirits, built and engined by Hawthorn Leslie (Shipbuilders), Ltd., Hebburn-on-Tyne, County Durham, for the Athel Line, Ltd., London, W.1. Main dimensions: 459 ft. overall by 61 ft. by 31 ft. to upper deck; deadweight capacity, about 10,000 tons. Hawthorn-Doxford four-cylinder combined-stroke opposed-piston heavy-oil engine, developing 4,450 b.h.p. at 112 r.p.m. Trial trip, October 12 and 13.

M.S. "GRANBY QUEEN."—Single-screw trawler, built by John Lewis and Sons, Ltd., Aberdeen, for Talisman Trawlers, Ltd., Lowestoft. First of a series of four similar vessels for these owners. Understood to be the first steel trawler to be launched in Scotland under the White Fish Authority's grant and loan scheme. Main dimensions: 113 ft. 6 in. overall by 20 ft. by 10 ft. 9 in. Six-cylinder Diesel engine developing 440 b.h.p. at 300 r.p.m., constructed by Crossley Brothers, Ltd., Openshaw, Manchester 11. Trial trip, October 14.

M.S. "OWERRI."—Single-screw cargo vessel, built and engined by Harland and Wolff, Ltd., Belfast, for Elder Dempster Lines, Ltd., Liverpool. Main dimensions: 425 ft. between perpendiculars by 62 ft. by 34 ft. to shelter deck; gross tonnage, about 6,200. Harland and Wolff-B. and W. five-cylinder single-acting two-stroke opposed-piston Diesel engine. Launch, October 14.

S.S. "MELIKA."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Afran Transport Co., Monrovia, Liberia (a subsidiary of the Gulf Oil Corporation, New York). Sixth vessel built for these owners. Main dimensions: 630 ft. between perpendiculars by 87 ft. by 45 ft. 6 in.; deadweight capacity, 32,020 tons on a summer draught of 34 ft. 2 in. Double-reduction geared turbines, developing a maximum of 13,750 s.h.p. at 108 r.p.m., constructed by Richardsons, Westgarth & Co., Ltd., Wallsend-on-Tyne. Steam supplied by two Foster Wheeler oil-burning boilers. Speed, 15¼ knots. Trial trip, October 15.

M.S. "BLACK PRINCE."—Single-screw vessel, to carry citrus fruits and general cargo, and with accommodation for twelve passengers, built by the Burntisland Shipbuilding Co., Ltd., Burntisland, Fife, for the Mediterranean trade of the Prince Line Ltd., London, E.C.3. Main dimensions: 345 ft. between perpendiculars by 52 ft. 7 in. by 32 ft. 4 in. to shelter deck; deadweight capacity, 4,900 tons on a draught of 21 ft. 9⅛ in. Hawthorn-Doxford four-cylinder opposed-piston Diesel engine, arranged to burn heavy-fuel oil and developing 3,300 b.h.p., constructed by Hawthorn Leslie (Engineers) Ltd., Newcastle-upon-Tyne, and installed by the shipbuilders. Launch, October 15.



**The search coil unit which forms part of an electronic apparatus for detecting non-ferrous metals and thus protecting mixing plant.**

## DETECTING NON-FERROUS METALS

Electronic equipment for detecting non-ferrous metals, and thus enabling mining and quarry machinery to be protected, has been developed by Metal Detection, Limited, Moseley-street, Birmingham 12. It consists essentially of a system of two mutually-perpendicular coils, each of which is a single turn of heavy-gauge copper tube. These coils are arranged so that one lies under the conveyor or chute carrying the material to be inspected, while the other surrounds it. They are rigidly supported by side plates on a bedplate and the whole assembly is mounted on shock absorbers. One of the side plates is removable so that the unit may be placed in position without cutting the belt. An illustration of this search coil unit is given above.

In operation a high-frequency electromagnetic field is set up in the coil unit by an oscillator which is housed in a separate cabinet, the system being adjusted to give a zero signal when there is no metal in the field. When, however, a piece of metal passes through the search coil the field is disturbed and the resulting signal is amplified. This signal operates a control relay which, in turn, stops the conveyor or automatically deflects the metal to waste. It may also light a signal lamp, sound a warning horn or operate a marking device indicating the position of the metal on the belt. When automatic deflection is employed the detector can be re-set after a pre-selected time delay or by a push button.

Variations in the supply voltage are regulated by a stabiliser, while mechanical vibrations are minimised by the use of single-turn coils and by a compensating stage in the control unit. The sensitivity of the device depends on the type and size of the material, the width of the conveyor and other factors. For instance, very small pieces of metal can be detected in phosphate rock or limestone, as these materials have no effect on the detector.

* * *

## COAL TUB VIBRATOR

### *Loads Increased by 14 per cent.*

Where tubs are used in a coal mine for carrying purposes, coal is usually poured into them from an overhead hopper or chute and the tub is only partially filled. This is due to the fact that voids are created between the falling lumps. To increase the volume held by a tub, loading vibrators of various types are used. One such device is the platform vibrator, of which over one hundred have already been installed. It is made by the Butterley Company, Limited, Derby, and is illustrated on the right.

In a report recently issued by the National Coal Board, the opinion is expressed that "there seems to be little doubt that vibrating platforms of this type can provide a very satisfactory short-term economical solution at any colliery where limited winding and haulage capacity tend to restrict production, and where the rate of loading tubs is sufficiently low to permit efficient operation of a vibrator." A further application is where tubs are in short supply. To estimate the possible increase in loads carried, the type of coal handled must be considered. Where the coal is friable with a large proportion of lumps and dust the vibrator has enabled loose coal to be shaken into the voids increasing the quantity in the tubs by 6 per cent. At another colliery where the coal was hard and fairly uniform in size and free of large lumps, an increase of 12 to 14 per cent. has been regularly achieved. The tubs in each case were nominally carrying 15 cwt. of coal.

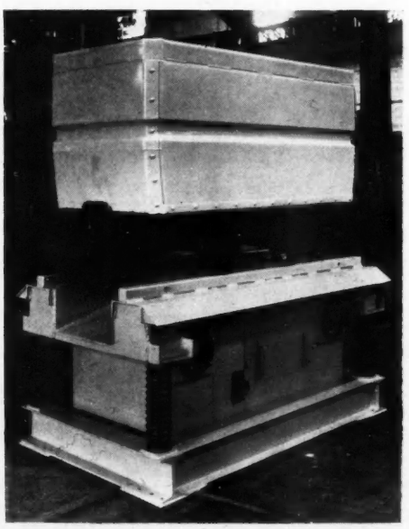
The vibrator platform illustrated is designed to be set in a pit so that it supports the tub during loading. The rails are arranged to align with the normal track. A second pit is usually prepared alongside the vibrator for inspection purposes and also to enable spillage and coal dust to be removed periodically. To prevent the spillage entering the machine there is a cover plate forming an inverted-V welded between the track; this is just visible in the illustration.

The platform carrying the rails rests on four helical springs, one at each corner, which are carried in turn by a base frame of I-section. A 5-h.p. motor mounted within the base drives an eccentrically-mounted weight through a chain and sprocket. Out-of-balance forces created by the movement of this gear induce a high-frequency oscillation which is transmitted through the platform to the tub being filled, causing the coal to settle down in the voids.

The driving mechanism is totally enclosed to protect it against dust and moisture, and the lubrication points are grouped together externally. To gain access to the motor, the platform and rails can be lifted off the springs as they merely rest upon these and are not attached directly to the supporting platform.

The vibrating gear runs in self-aligning ball races carried in a heavy housing. The makers state that all parts of the machine have been designed to withstand arduous pit service. Five different sizes of this machine are being made to suit the different types of tubs used in collieries. They cover tubs of the following capacities: 1, 2¼ (two models), 3½, and 5 tons, and vary in length, width and height.

Tests made in pits have shown that the over-rope type of haulage, where the rope runs over the top of the track, carried small coal on to the track. When the tubs were moving, however, the spillage was less. Samples of the atmosphere taken in the vicinity of the vibrator have shown no noticeable increase in the airborne dust.



**Vibrator before installation. A motor-driven oscillating gear vibrates the platform and the truck being filled, shaking the loose coal into voids created by large lumps.**

## 50-CYCLE SINGLE-PHASE ELECTRIC TRACTION

### *Successful Results on the Valenciennes-Thionville Line*

The recent conversion of the section of the French Railways between Valenciennes and Thionville to electric traction on the 22-kV single-phase 50-cycle system is part of a larger programme involving the lines between Lille, Metz, Strasbourg and Basel. It is of importance owing to the heavy freight traffic carried over severe gradients, this traffic being mainly composed of complete train loads of iron ore, coal, coke and limestone. At the present time, the conversion involves 225 route miles of track, to supply which six sub-stations are to be provided, compared with the 23 which would have been required had the 1,500-volt direct-current system been used.

Moreover, it has been possible to reduce the cross-section of the overhead conductors from 0·744 sq. in. on the direct-current system to 0·233 sq. in. owing to the higher voltage of the single-phase system, with corresponding savings in cost.

#### LOCOMOTIVE DETAILS

The success of this scheme, however, depends on the practicability of building locomotives to work satisfactorily on a 50-cycle supply. On page 16, *ante*, we gave an account of the Co-Co and Bo-Bo locomotives that have been designed for this purpose; and recorded that the former were to be capable of hauling 1,800-ton trains up gradients of 1 in 100. The Bo-Bo locomotives, which are intended for mixed-traffic work will have maximum speeds of 65 and 75 m.p.h., depending on whether single-phase motors or ignitron conversion is used.

One of the Co-Co locomotives, which weighs 120 metric tons and was built by Société Alsthom, is illustrated below. It is equipped with four 680-h.p. motors and between the date of its delivery on July 29 and September 10 has run 13,390 miles. In the course of this duty the average weight of the trains hauled was 1,380 metric tons, although 1,800 metric tons was hauled on occasion.

Two of the Bo-Bo locomotives, both of which have been built by Société Le Materiel Traction Electrique, Jeumont, have also been delivered. One of these is equipped with four 18-pole 680-h.p. single-phase motors and between July 13 and September 10 covered 19,871 miles, hauling trains of an average weight of 685 metric tons. The load, however, frequently exceeded 900 tons, thus exceeding the designed performance.

The other Bo-Bo locomotive is equipped with ignitron rectifiers and "undulating" current motors. It was delivered on July 17 and between then and September 10 ran 17,833 miles, hauling trains of an average weight of 675 metric tons. Loads of 1,000 tons were, however, often exceeded; and it was also found possible to start trains of 1,200 metric tons on a rising gradient.

Additional units of designs identical with these prototypes are now being delivered and should reach seven or eight a month at the beginning of next year. A further series of 20 goods locomotives are also being built by the Société Oerlikon and delivery of these will also begin shortly.

* * *

## LONG SUBMARINE TELEPHONE CABLE

### *Aberdeen and Bergen Connected*

The longest submarine telephone cable link in the world has recently been completed between Aberdeen and Bergen, a distance of just over 300 nautical miles. The cable, which will contain seven submerged repeaters and will enable 36 simultaneous two-way channels to be provided, is of the coaxial type and is similar in construction to the Netherlands-Denmark cables which were laid in 1950. Like them too, it was manufactured by Submarine Cables, Limited, at the Telcon Works, Greenwich, London, S.E.10.

The inner copper conductor of the cable consists of seven wires, each 0·0765 in. in diameter round which a 0·775 in. by 0·015 in. tape is longitudinally folded, the interstices being filled with compound. This construction combines flexibility, the low direct-current resistance desirable for supplying power to the repeaters and the transmission efficiency necessary at high carrier frequencies. A layer of Grade 2 polythene, mixed with 5 per cent. poly-isobutylene and a small amount of antioxidant to guard against deterioration during processing, was extruded on to this conductor in a single operation to a diameter of 0·935 in. The outer copper conductor consists of a layer of six 0·475 in. by 0·015 in. tapes, which were applied with a long lay and are bound by an overlapping short-lay tape 0·004 in. thick. Protection against corrosion is provided by a Teleconax tape, over which is a serving of two layers of tarred jute yarn. The superimposed armouring consists of either 15 2-s.w.g. or 21 6-s.w.g. galvanised steel wires according to the depth at which the cable is laid. Overall are two layers of tarred jute yarn which were applied with bituminous compound. To minimise extraneous electrical interference the outer conductor is insulated with Telcothene for 0·5 nautical mile at each end, is covered with lead and armoured with twenty 2-s.w.g. wires.

#### REPEATER ARRANGEMENTS

Frequency bands of 24 to 168 kilocycles will be used between Aberdeen and Bergen and of 208 to 352 kilocycles in the opposite direction. This will be made possible by the inclusion of seven submerged repeaters at spacings of about 38·8 nautical miles. These repeaters differ in design to some extent from those standardised by the Post Office for use in shallow water. They are of "torpedo" shape with a cable entry at each end. The cases were made by the Telegraph Construction and Maintenance Company, Limited, and the internal electrical equipment by Standard Telephones and Cables, Limited. The latter firm is also supplying the terminal equipment. It will be possible to energise the repeaters from both ends of the cable by means of direct-current supplied through the inner conductor and returning by terminal earth plates. These plates will be well separated from the cable to avoid damage by electrolytic action.

The new submarine link will be connected to London and Oslo by land coaxial cables and will enable direct telephone facilities to be provided between the two capitals instead of, as hitherto, via Holland and Denmark.

* * *

## WESTLAND S-55 HELICOPTER

### *Certificate of Airworthiness*

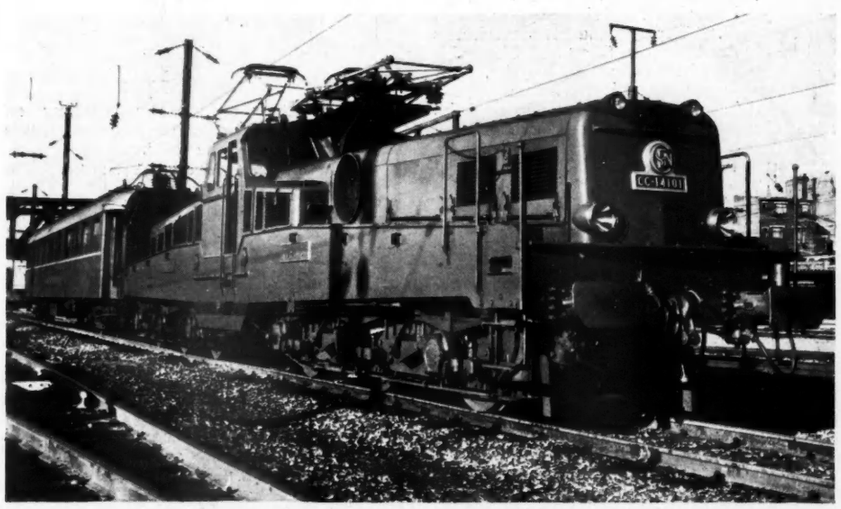
Following successful completion of all performance trials and a period of intensive operating experience in the hands of an independent operator, the Air Registration Board has issued a full Certificate of Airworthiness for the Westland S-55 helicopter, constructed by Westland Aircraft, Limited, Yeovil. The S-55 is capable of carrying eight passengers and their baggage, in addition to a crew of two, and is the first British-built helicopter of this size for which a full Certificate of Airworthiness has been issued.

Issue of the certificate coincides with the delivery to British European Airways of the first of the two S-55's ordered by the Corporation for their forthcoming passenger service between London Airport and Waterloo which is to start next April.

The S-55 has a single rotor and is powered by a Pratt and Whitney "Wasp" engine which may later be replaced by a British engine now under development. It has all-metal main-rotor and tail-rotor blades which give maximum durability in all climates, and the main rotor is so placed that passengers may embark and disembark while it is still turning.

The all-up weight of the aircraft is 7,500 lb.; it has a maximum speed of 110 m.p.h. and a normal cruising speed of 90 m.p.h.

Manufacture of the prototype components of the Westland S-55 (the Service version of which was named the "Whirlwind") was started in 1951, and since the first production model was delivered to the French Navy nearly 50 of the type have been built and delivered. They are in service with the Royal Navy and Royal Air Force. Five S-55's were recently delivered to British and Norwegian whaling companies and will operate from factory ships during the forthcoming whaling season. An order approaching 100 of the military version has been placed by the Ministry of Supply and some twenty of these have already been delivered.



**A 680-h.p. 50-cycle single-phase locomotive which is now undergoing trials on the Valenciennes-Thionville section of the French Railways.**

# TRANSATLANTIC TELEPHONE CABLE*

## A MAJOR STEP FORWARD IN INTERNATIONAL COMMUNICATION

*By M. J. Kelly; Sir Gordon Radley; G. W. Gilman; and R. J. Halsey*†

In December, 1953, plans were announced by the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation for laying the first transatlantic telephone cable system. This was to provide 35 high-grade telephone circuits between the United Kingdom, Canada and the United States and complete commercial operation was contemplated at the end of 1956. The two cables on the main crossing will each be nearly 2,000 nautical miles long and will contain 52 submerged repeaters laid at depths up to 2,000 fathoms. The longest submarine cable at present in use is less than 200 nautical miles long and no cable contains more than four repeaters. The new system will therefore represent a major step forward in the evolution of the transatlantic telephone service, which began in 1927 with the establishment of one long-wave radio circuit between London and New York.

### EARLIER PROPOSALS

In 1928, a proposal for a single-circuit telephone cable between Ireland and Newfoundland, a distance of 1,800 nautical miles, was made by the Bell Telephone System and discussed with the British Post Office. It called for a continuously loaded non-repeatered coaxial cable operating at a maximum frequency of about 3,800 cycles. The central conductor was to be loaded with Perminvar tape and the insulation was to be of Paragutta, both of which were new materials. This cable was never laid, but during the depression following 1930 studies and experiments were made in the laboratory and at sea in search of improvements. In particular, attention was paid to the problem of maintaining the structure of the cable during laying and a design was produced in which, in contradistinction to established ideas at the time, the lays of the tape loading and the tapes of the copper inner and outer conductors and of the armour wires were in the same direction.

By 1932, the rapidly developing electronic art made it possible to contemplate the design of a long-distance deep-water cable associated with submerged repeaters containing long-life valves, which would be capable of transmitting a number of, instead of only one, carrier telephone channels. The system was to consist of two non-loaded coaxial cables, one for each direction of transmission into which repeaters were to be spliced at regular intervals. These repeaters had to be designed to withstand the shocks of laying and recovery and of the pressure of water encountered. The valves had to operate at a sufficiently low cathode power and anode potential to make it feasible to supply power to the repeaters at a safe working potential. Finally, the repeaters had to have sufficiently long lives to operate with small likelihood of failure over a period of some 20 years.

### THE 1952 NEGOTIATIONS

From 1938 onwards the British Post Office laid a number of cables incorporating repeaters in shallow waters, while in 1950 the Americans installed a pair of cables between Key West and Havana. These cables included six repeaters, four of which are at depths ranging from 20 to 950 fathoms. In the same year the Post Office set up a committee to report on the possibilities of repeatered telephone cables across the Atlantic, and early in 1952 re-opened negotiations with the American Telephone and Telegraph Company. At that time the valves and other components, which had been selected for their reliability in service, had been under observation in America since about 1940. Cable and repeater designs for a transatlantic project had been given practical trials on the Key West-Havana route and were therefore recommended for use between Newfoundland and Scotland. It was also recommended that the British shallow-water design should be used between Newfoundland and Nova Scotia, owing to its lower cost.

### CABLE ROUTE

The new cables will be laid between Oban in Scotland and Clarenville in Newfoundland, this route being chosen so as to clear the existing telegraph cables and to avoid known "holes" in the ocean bed. Both cables will be about 1,950 nautical miles long and each will be equipped with 52 repeaters. The greatest depth at which a repeater will lie will be about 2,300 fathoms, but most will be at depths between 1,200 and 2,000 fathoms. Three alternative schemes for connection between Clarenville and Nova Scotia were considered. That finally selected consists of laying a cable about 62 statute miles overland to Terrenceville at the head of Fortune Bay and thence for a distance of 274 nautical miles in coastal waters, at depths up to about 250 fathoms, to Sydney Mines. The single cable will be equipped with 16 repeaters, two of which will be on land.

### CIRCUIT CAPACITY

The cables between Clarenville and Oban will have transmission frequency bands from 20 to 164 kilocycles; and will provide 36 carrier telephone circuits with channels at 4 kilocycle spacing. The capacity of the cable between Clarenville and Sydney Mines will be somewhat greater, as it is planned to transmit a 20 to 260 kilocycle band from Sydney Mines to Clarenville and a 312 to 552 kilocycle band in the opposite direction. The cable will therefore provide 60 carrier telephone circuits with channels spaced four kilocycles apart. The traffic operating terminals will be in London, New York and Montreal. There will be 29 circuits between London and New York and six between London and Montreal. Telephone and telegraph circuits will be provided between Oban and Clarenville in the frequency band below 20 kilocycles.

As regards performance it has been agreed that the target for the frequency characteristics of the channels between London and New York and Montreal should be at least as good as those specified by C.C.I.F. for a 2,500-km. international circuit. The "via net loss" for the transatlantic circuits will be 0·5 decibel, measured at 800 and 1,000 cycles between London and New York (or Montreal). With a net loss of this order on circuits, which will have a one-way transmission time of about 35 milliseconds, echo control will be necessary and the best method of applying this is being studied. Terminating circuit packs will add 2 decibels to the loss at New York and 3·5 decibels in London for calls between the two cities. Thus the normal attenuation will be 6 decibels. Variations from normal attenuation will be restricted to a standard deviation of 1·5 decibels. This will put a severe requirement on the individual links, which it will be difficult to meet.

A pilot tone of about 84 kilocycles will be injected into each group of twelve channels at a point where the channels appear in the 60 to 108-kilocycle range. Measurement of the re-

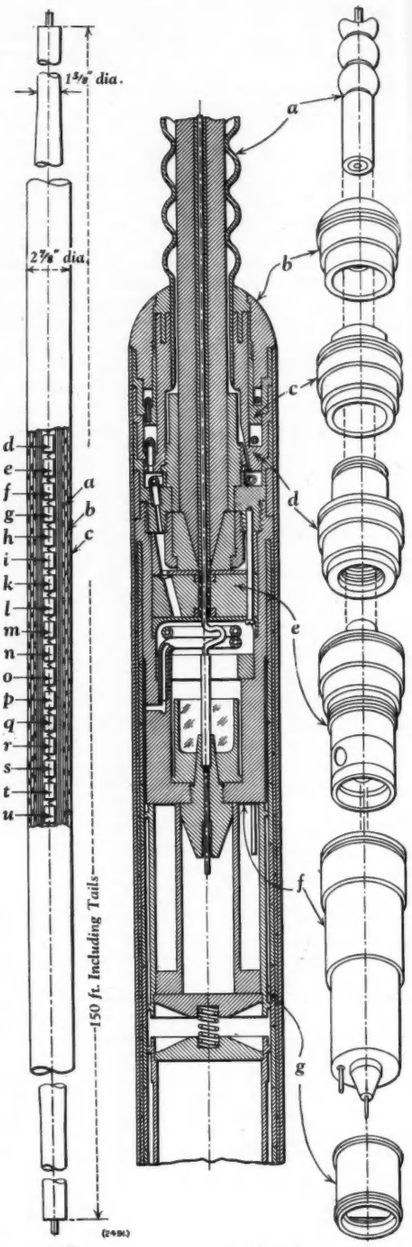



Fig. 1 Fig. 2

**Fig. 1 Structure of repeater container on Clarenville-Oban section of the new transatlantic telephone cable.**

*a.* Armour bedding and corrosion protection.
*b.* First layer of armour wires.
*c.* Second layer of armour wires.
*d.* Input terminal.
*e.* Input blocking capacitor.
*f.* Earthing capacitor.
*g.* Crystal.
*h.* Input network.
*i.* First-stage pentode.
*k.* First inter-stage network.
*l.* Second-stage pentode.
*m.* Second inter-stage network.
*n.* Third-stage pentode.
*o.* Output network.
*p.* Feedback network.
*q.* Feedback network.
*r.* Gas diode.
*s.* Drier.
*t.* Output blocking capacitor.
*u.* Output terminal.

**Fig. 2 Repeater assembly on Clarenville-Oban section.**

*a.* Core tube, 7 ft. long, Vistac filled and coiled.
*b.* Nosing parts.
*c.* Cover.
*d.* Protective-tube assembly.
*e.* Rubber-seal assembly.
*f.* Glass-seal assembly.
*g.* End terminal unit.

* Paper read before the Institution of Electrical Engineers on Thursday, November 4. Abridged.

† Dr. Kelly and Mr. Gilman are with the Bell Telephone Laboratories. Sir Gordon Radley and Mr. Halsey are with the British Post Office.

ceived level of the tone will give an indication of the overall attenuation. Later the received tone may be used to control automatically the gain of the terminal amplifiers on each group. In addition, injected 92-kilocycle tones will be transmitted to indicate the attenuation of each section.

### CABLE DESIGN

The cables between Scotland and Newfoundland with their associated repeaters will be of the type now in operation between Key West and Havana.* They will consist of a solid-dielectric structure covered by the usual jute and armour for protection and strength. The central copper conductor will consist of a solid wire 0·1318 in. in diameter surrounded by a layer of copper spiralling and abutting tapes. These tapes will be 0·0145 in. wide and will be formed to fit closely round the wire with a minimum of voids. Such a composite structure has better flexibility and resistance to breakage than a solid conductor and has better alternating and direct-current resistance than a stranded conductor of the same external diameter. The return conductor will also be a flexible copper structure, consisting of a single layer of six abutting spiralling tapes 0·016 in. wide formed into a tube. It will be covered with an 0·003-in. overlapped helical tape for protection against teredo. The various layers of tape and armour are applied in the same direction of lay for the reasons given above.

Polythene will be used as the dielectric, as it has a lower permittivity and a greater electric strength than Paragutta. It is also more uniform in its characteristics, less pervious to sea water and possesses more desirable mechanical properties. The dielectric between the centre and return conductors will be 0·62 in. in diameter.

Teleconax tape will be wound over the teredo tape and will be covered with one serving of jute. Cable which is to be laid in water not deeper than about 300 fathoms will be armoured with 12 galvanised mild-steel wires, each 0·3 in. in diameter. The armouring for the landing cables will be similar, but there will be an extra layer of wire. For moderate depths, 18 galvanised mild-steel wires each 0·165 in. in diameter, will be used, while for depths greater than 700 fathoms the armouring will consist of 24 high-tensile steel wires of 0·086 in. diameter, each wire being taped. The overall diameter of the cable will vary from 2·68 in. for the shore ends to 1·21 in. for the lengths laid at the greatest depths.

### REPEATER ASSEMBLY

The repeater structure will be a flexible bulge in the cable. It will be 8 ft. long and 2·8 in. in diameter and will taper for a distance of about 20 ft. at each end down to the cable diameter. The cable armouring will be continued over the repeater housing with extra wires to give complete coverage. To prevent the structure twisting during laying there will be a second layer of wires with opposite lay. The repeater itself will be enclosed within an 8-ft. long series of cylindrical sections inside the housing.

The structure of the repeater container is shown in Fig. 1. It will be flexible and during laying will pass readily over the cable drum and bow sheave without requiring the ship to be stopped. To attain this flexibility, the repeater elements within the container will be mounted inside a series of Lucite (methyl-methacrylate) cylinders, successive units being held together by a spring assembly to form an articulated system. Surrounding these cylinders will be a series of butt-end steel rings in two layers, the joints between successive rings in the two layers being staggered. Over the rings, and supported by them against collapse at sea-bottom pressure, will be an envelope of copper tube and over this will be the protective coatings and armouring wires.

* See J. J. Gilbert: "A Submarine Telephone Cable with Submerged Repeaters." *Bell System Technical Journal*, vol. 30, page 65 (1951).

The repeater section will be terminated at each end by a system of seals. This system will comprise a glass-metal seal adjacent to the repeater elements; a plastic seal moulded to the cable insulation; and at the extreme ends a 7-ft. long seal formed within a copper tube, which will be an extension of the repeater housing. In order to penetrate this housing the sea water will therefore have to travel a long multi-barriered path. All the seals will be adapted for the sea-bottom pressures that they may have to withstand. Fig. 2 shows a partially-sectioned portion of the seal and further details of the repeater structure.

### VALVE DESIGN

The valves will be suppressor-grid pentodes, the details of which have not been essentially altered since 1941. They will have a large cathode area, low cathode temperature (630 deg. C.), low anode potential (60 volts), large internal spacing between the elements and will generally be of rugged and shock-proof construction. In addition to the valves, about 60 other circuit elements, such as resistors, capacitors, inductors, transformers and crystals, will have to be accommodated in a volume no greater than that of a 3-in. cube. These elements have been designed and fabricated to avoid all possible risk of failure in service and to meet the requirements of ruggedness and reasonably small size. Cost has been a less important factor than in most other applications.

The 52 repeaters in each cable will be located at intervals of about 37 nautical miles and will be fed with direct current from each shore end. Each repeater will produce a drop of 55 volts at an initial current of 225 milliamperes, but after a number of years it will be possible to increase the current to a maximum of 245 milliamperes to offset any deterioration in valve emission. Frequencies in the range of 167 to 174 kilocycles will be used to keep track of the performance and condition of the separate repeaters as on the Key West-Havana system.* After a cable has been repaired its length will be greater than before, thus upsetting the balance between cable loss and repeater gain. To compensate for this low-gain "repair repeaters" will be inserted when a repair is made in deep water.

### THE CLARENVILLE-SYDNEY MINES SECTION

The structure and dimensions of the conductors and core of the submarine cable on the Clarenville-Sydney Mines section will be identical with those of the cable between Clarenville and Oban. The land cable will also be basically the same, but being more subject to electrical interference will be screened by laying soft-iron tape over the inner conductor. This tape will be protected by a polyethylene sheath, over which a jute bedding and armouring will be applied. The cable will be laid in a trench about 30 in. deep, where the temperature is expected to have an annual variation of about 35 deg. F. and a maximum daily variation of about 2 deg. F. Guard wires to protect the system against lightning will be laid above the cable.

The 16 repeaters in this section will be located about 20 nautical miles apart. The electrical equipment will be mounted in an inner sealed cylinder, 4 ft. 2 in. long and 7¾ in. in diameter, which will be filled with dry nitrogen. This cylinder will be mounted between brazed-in bulkheads in the pressure-resisting outer housing, which will be about 9 ft. long and have a maximum diameter of 10½ in. The glands will be polyethylene mouldings, which will be integral with the dielectric and will be shrunk on to castellated bosses. The cable armouring wires will be made-off under clamps to transfer the laying tension to the housing. Electrically, the repeaters will be arranged to give both-way amplification.

The wide frequency range to be transmitted over the cable between Clarenville and Sydrey Mines will be made practicable by the use of high performance valves with a mutual conductance of 6,000 micro-ohms. The formation of an interface between the cathodic cores and the emissive material will be prevented by the use of pure platinum for the former. The heater of each valve will require about 300 milliamperes at 5·5 volts and the six heaters in each repeater will be series connected. The cathode anode potential difference (90 volts) will be derived from a separate resistor carrying the line current.

* *loc. cit.*

The accommodation afforded by the rigid housing has not only permitted the complicated circuits of the British repeaters to be accommodated but will also make it possible to design some of the components on more generous lines than those in the American repeaters. For example, a non-polar dielectric of mineral oil will be used in the capacitors instead of polar castor oil, thus reducing the electric stress to about one third. Silvered-mica capacitors will only be used where the polarisation is less than 10 volts. At all other points the capacitors will be of the sealed oil-impregnated type.

The repeaters on the Clarenville-Oban section will initially require a total driving voltage of about 3,900 volts, increasing later to about 4,450 volts, or to 4,700 volts if it is necessary to introduce additional repeaters after repairs. The maximum voltage on the cable will be about half this. On the Clarenville-Sydney Mines section the necessary total driving voltage will be about 2,300 volts and, if necessary, it will be possible to feed this from one end only.

The generators on the Clarenville-Oban section will derive their constant-current feature by feeding through high-impedance pentodes with a mechanical regulator to absorb all but short-term variations. To assist continuity the load will be shared between two generators at each end, both of which will be capable of supplying the full load. Transductor-controlled power units will be used on the Clarenville-Sydney Mines section. The motor-generators will normally be supplied from the mains, but to ensure the continuity of the direct-current power in the event of failure, Diesel engine-driven alternators will be started up automatically after an interval during which the motor-generators will be supplied from a battery.

### LAYING ARRANGEMENTS

All the cable will be laid by H.M.T.S. Monarch, which will be fitted with new drums as well as bow and stern sheaves of 7 ft. diameter. Roller guides with a minimum radius of 3 ft. 6 in. will replace the existing spider wheels and "spectacle" guides in order to ensure freedom from sharp bends. Three new dynamometers will also be installed, and electrically-sensitive pressure cells will be provided to operate indicating and recording instruments and to enable the tension on the cable to be controlled closely as it is paid out.

From Oban the transatlantic circuits will be taken to London by carrier cable, one running via Glasgow and the other via Inverness and Aberdeen. On the American side a micro-wave radio-relay system will connect Sydney Mines with Portland, Maine. From Portland, the circuits will be extended to New York by carrier cable or radio relay. Cable connection to Montreal will be effected at a point on the radio-relay system near the U.S.A.-Canada border.

(*Editorial comment in Weekly Survey*)

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## LECTURES ON ATOMIC ENERGY

Two lectures on "Atomic Energy in the Modern World," will be given at the Senate House, University of London, Malet-street, W.C.1, on Saturday, November 20. The first, on "Atomic Energy Made Easy," by Sir Christopher Hinton, will commence at 3 p.m., and the second, on "Industrial Power from Atomic Energy," by Mr. R. V. Moore, at 5 p.m. Tickets are obtainable from the above address, price 3*s.* 6*d.* each, including tea.

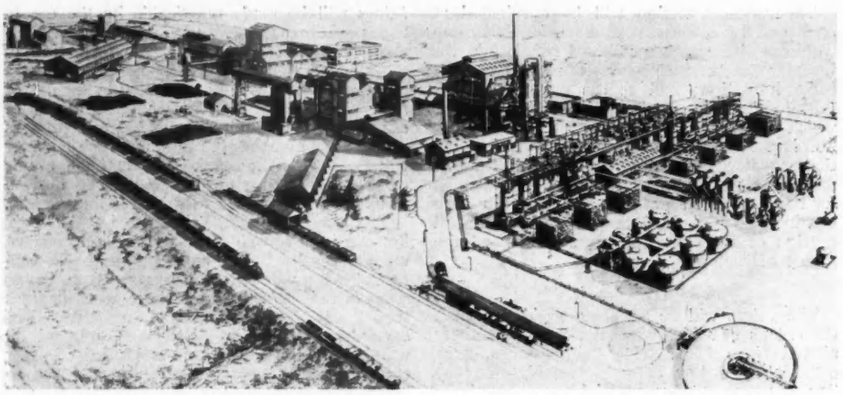


**Fig. 1 Sketch of the completed plant; on the extreme right are the acid-storage tanks and on the extreme left the cement-production plant. Raw materials, anhydrite, coke, sand and shale, are fed from the dumps to the crushing and drying house in the centre and thence to the coal-fired rotary kilns. Clinker for cement flows to the left and sulphur dioxide for conversion to acid to the right.**

# SULPHURIC ACID PLANT

## ANHYDRITE PROCESS AT WIDNES INCLUDES CEMENT PRODUCTION

The sulphuric-acid plant being built at Widnes by the United Sulphuric Acid Corporation, Limited, will commence production early next year. The Corporation has been formed by eleven firms, all of which are large users of sulphuric acid, and has been licensed by Imperial Chemical Industries, Limited, to use the anhydrite process developed at Billingham. When in full production, the factory will use about 240,000 tons of anhydrite per annum to give 148,000 tons of sulphuric acid and 132,000 tons of cement clinker. The last will be transported to an adjacent plant being built by the Blue Circle group for the manufacture of Portland cement. The total cost of the sulphuric-acid plant is estimated at £5 millions.

### ANHYDRITE PROCESS

The anhydrite process consists fundamentally in heating an accurately proportioned mixture of calcium sulphate with materials containing carbon, silica, alumina and ferric oxide, thereby producing simultaneously cement clinker and gases containing sulphur dioxide. The latter gas is then converted to sulphuric acid by the orthodox "contact" process.

The raw materials to be used at Widnes in addition to anhydrite are coke, sand and shale. Coal is also used, not primarily as a raw material but in pulverised form for firing the kilns in which the mixture is heated: its ash, however, inevitably forms part of the mixture. The anhydrite will come from Cumberland, but the other materials are available locally.

The plant at Widnes is not yet complete, but a sketch of its final appearance is given in Fig. 1. On the extreme left is the cement plant, and on the right the storage tanks for the acid produced. Raw-materials dumps can be seen in the centre and to the left, from which the materials are fed to the crushing and drying house in the centre.

### RAW-MATERIALS HANDLING

The anhydrite will be brought by rail from the Long Meg, Cumberland, mine of British Plaster Board (Holdings), Limited. Transport will be in 25½-ton bottom-opening wagons which will deliver to a covered hopper. This can be seen almost in the centre of Fig. 1. A skip hoist lifts the ore on to a belt conveyor by which it can be taken directly to the crushers, or diverted to the storage dump by a travelling tripper. A mechanical excavator can reclaim it from the dump and return it to the belt through a travelling hopper. The dump has a capacity of about 12,000 tons. An angle hoist raises the anhydrite after crushing to the conveyor which feeds it to the storage bunkers in the kiln feed house. Two Symons crushers are used, driven by 75-h.p. motors.

The sand, shale and coke are taken from their dumps and transported by the same angle hoist to the wet-storage bunkers from which they are delivered by table feeders to two Head, Wrightson rotary driers. The shale is broken by hammer mills before being taken to the bunkers. The driers are oil fired by Laidlaw Drew burners and are fitted with a flame detector, that is not affected by radiant heat, and gives warning if the flame is extinguished. One drier will normally be used for sand and shale and the other for coke only. At the dry end there are fume extractors and dust cyclones, the latter being arranged for recirculation through the driers. A gravity-bucket conveyor takes all the materials up to the dry-storage bunkers, a selective tipping mechanism being used to keep them separate. Throughout the plant, from the driers onwards, there are two parallel and identical flow lines to enable repair and maintenance work to be carried out without interrupting the continuous process. From the dry bunkers, the materials are automatically weighed on to a belt. It is important to keep the proportions correct so that good-quality cement clinker shall be formed, as the capital cost of plant for the anhydrite process can only be justified by the production of good-quality cement in addition to sulphuric acid. The belt delivers the materials to a rotary ball mill, driven by a 900-h.p. auto-synchronous motor, in which they are ground and mixed before being conveyed to the "raw meal" silos which can be seen behind the kilns in Fig. 2. Transport to and from these silos is by fluidising and an air current.

### COAL-FIRED KILNS

The raw meal is then fed into the upper ends of the rotary kilns (shown on the right in Fig. 1 and on the left in Fig. 2) where it is heated, sulphur-dioxide gas being evolved. Heating is effected by burning pulverised coal, supplied from Herbert attritors, in the opposite, lower, ends of the kilns. The burners project into the kilns for a length of about 30 ft., and are unsupported over this length. The kilns themselves are similar to orthodox cement kilns, and are 355 ft. long, lined throughout with firebrick. The interior is smooth, and the meal slowly works down it to the bottom where, being now clinker, it falls into the 12 dischargers which can be seen round the lower end of the kiln in Fig. 2. These discharge from their upper ends so that the clinker is forced up hill again for a short distance, becoming cooled in the process.

A hopper beneath the dischargers guides the clinker on to shaker conveyors which feed it to jaw crushers. After crushing, it is automatically weighed and conveyed to bunkers from which it is elevated and taken across an overhead gantry to the covered clinker store. This building, which has a capacity of about 10,000 tons, can be seen on the left in Fig. 1, and from this store, the clinker is conveyed to the cement works, being weighed in transit.

The gases leaving the kilns are mainly a mixture of sulphur dioxide, oxygen and nitrogen. They are both hot and dusty, so that cleaning and cooling are necessary. The bulk of the dust is removed by passing the stream through a smokebox and then a cyclone (the two flow lines still running parallel but separately), after which the gases are cooled and nearly all the remaining dust is removed in a cooling tower over which water is pumped. An acid-resistant lining is used in the towers, which are also ring-packed to ensure a thorough scrubbing of the gas. For the succeeding stages, most of the pipework is rubber lined to prevent corrosion. To remove the last particles of dust and mist, the gases are next passed through a battery of

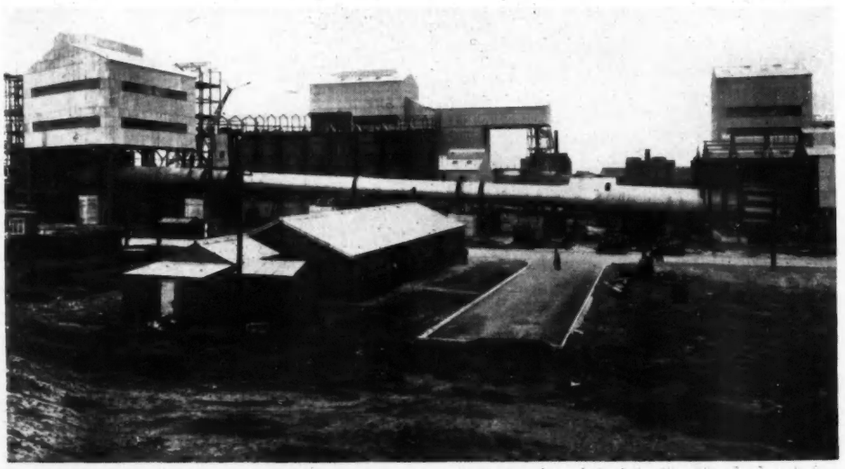


**Fig. 2 The rotary kilns, one complete and one under construction, are 355 ft. long. The feeder house is on the left and the firing and discharge house on the right.**

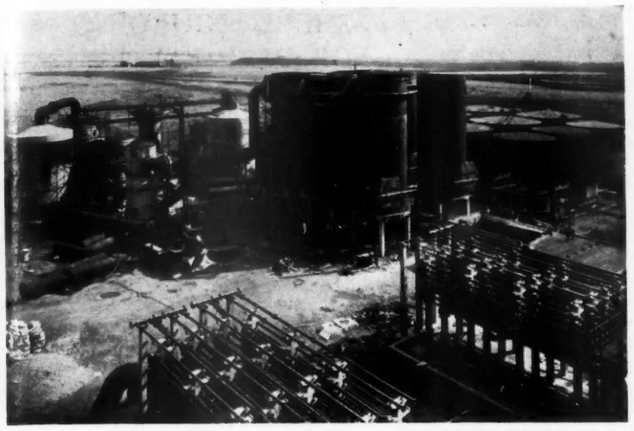


**Fig. 3 Circulating acid is cooled by the heat-exchangers in the foreground, and the sulphur dioxide is converted to sulphur trioxide in the towers on the left. The sulphur-trioxide coolers are in the centre and the acid-storage tanks on the right.**

Simon-Carves-Ferranti electrostatic precipitators. These can be seen, as a series of vertical columns, in Fig. 1. A spare pair is provided which can be switched to either flow line, to enable repairs and maintenance to be carried out.

## CONVERSION BY CONTACT PROCESS

As stated earlier, the conversion of sulphur dioxide to sulphuric acid is carried out by the orthodox " contact " process. The gas from the precipitators passes through a drying tower, in which water is removed by the counter-current circulation of strong sulphuric acid. Banks of water-sprayed coolers are provided for the acid and may be seen in the foreground in Fig. 3. At this point in the gas line, Bryan Donkin blowers are fitted; hitherto the gas has been sucked along, but now, in its clean dry state, it passes through the blowers and is forced into a multi-stage converter. This can be seen on the left in Fig. 3. In it, the sulphur dioxide combines with the oxygen in the gas to form sulphur trioxide, the reaction being promoted by a vanadium catalyst. The reaction is exothermic and heat exchangers are used between the stages to keep the gases at a proper temperature. There is a preheater for initiating the reaction. The sulphur trioxide formed is then taken through three annular cooling towers seen in the centre of Fig. 3. They are also visible in Fig. 1. The third of these towers is water cooled.

In the absorber towers which follow, the sulphur trioxide is absorbed in strong sulphuric acid. In one line, however, part of the gas is absorbed in an oleum tower. The strength of the acid leaving the towers is kept constant by dilution with water, and the net " make " of acid is pumped away to the storage tanks, which can be seen on the right in both Figs. 1 and 3. From the storage tanks the acid is pumped to the loading terminal, one side of which feeds to rail and the other to road tankers. Any unconverted sulphur dioxide in the gas leaving the absorbers is removed by tail-gas scrubber towers before the gas is released to the atmosphere.

## WATER SUPPLIES

The main contractors for the factory are Simon-Carves, Limited, Stockport, in collaboration with Simon Handling Engineers, Limited, who are responsible for the materials handling and preparation equipment. The factory site covers about 66 acres and has its own railway sidings. A 300-h.p. Hunslet Diesel locomotive will handle wagons within the boundaries. On the whole the ground has proved satisfactory, the only piling required being for the kiln foundations. Fortunately, the drainage system was completed early and it was possible to keep the site reasonably dry during the excavation of pits and foundations. The work of scraping and levelling was begun in October, 1952, and by the end of 1953 the main pits for the handling equipment had been excavated and concreted.

Cooling water for the whole plant will be drawn from the Mersey at Fiddler's Ferry, about 2½ miles east of the main site. A pump house has been erected there with two vertical-spindle Lee Howl centrifugal pumps, each of 300,000 gallons per hour capacity. These deliver the water through a 24-in. cast-iron pipe to the rotary Dorr clarifier at the factory. At the pump-house site, a large cofferdam had to be constructed to enable excavations to be carried out for the pump wells. After the work had been completed, the cofferdam piles were removed by underwater burning carried out by frogmen.

The Dorr clarifier, which can be seen on the right foreground of Fig. 1, is 120 ft. in diameter and 15 ft. deep at the centre. The clarified water discharges over a circumferential weir into a concrete sump from which it is distributed over the site by three Worthington-Simpson cooling-water pumps, each capable of handling 140,000 gallons per hour. Residual sludge is removed from the clarifier by two Dorr Oliver adjustable-stroke sludge pumps. In the clarifier is an emergency gate which can be opened if required to allow the water to drain into the pump sump. It is estimated that a three-hours supply would be available in this way, should there be a failure at the river pump house.

## ALKATHENE DRAIN

After use, the cooling water and drainings from the plant, which may be acidic, are taken by open flumes to an effluent-collecting basin. To handle the effluent, the flumes are made of boards treated with Tanalith and covered with lead; from the collecting basin glazed-stoneware pipes carry the liquor to the edge of the site. From this point, a 36-in. drain of Alkathene, believed to be the largest in Britain, leads back to the river Mersey, passing underneath the St. Helens canal on the way. Since Alkathene is a flexible material, the pipe was embedded in concrete and had projections attached to it which keyed it in place. These are to prevent any tendency to collapse should there be any suction on the pipe.

Steam for process work and space heating will be provided by two oil-fired Paxman Economic boilers, one of 6,720 lb. per hour capacity and the other of 2,240 lb. The feed water is treated by the lime-soda process and is delivered to the boilers by Weir reciprocating pumps. Much of the steam produced will be used for heating the fuel oil, both in the tanks and pipelines, and some for the raw-material dryers and the preheater. The water used for acid dilution is from the town's supply. Electricity is supplied to the factory substation at 33 kV and transformed to 6·6 kV at the factory bus-bars. There is also an alternative supply at 6·6 kV which feeds the bars directly.

Throughout the plant a system of planned preventive maintenance will be used, and for this purpose all the smaller motors have been standardised. For maintenance work, the excavator normally used to reclaim the anhydrite can be fitted with a jib. There is a well-equipped workshop which will be capable of carrying out most of the repair work required.

## CEMENT MANUFACTURE

As has been stated earlier, it is only the fact that the clinker produced from the kilns can be used as cement that renders the anhydrite process an economical one. The plant for dealing with the clinker has been erected close to the clinker store by Associated Portland Cement Manufacturers, Limited. It covers an area of 3·2 acres; the buildings can be seen on the extreme left of Fig. 1. Fig. 4 shows the flow line.

The clinker is weighed out from the store and fed by a vibrating feeder and an elevator belt to the clinker hopper which has a capacity of 250 tons. Interlocks are provided between the United Sulphuric Acid Corporation's equipment and the Associated Portland Cement Manufacturers' elevator to ensure a proper sequence of operations.

To produce cement of the required composition, gypsum must be added to the extent of 5 per cent. The gypsum will be delivered by rail and discharged by hand, either to the stock-pile or to the elevator feeding the hopper. Gypsum and clinker are discharged from their hoppers by gate-controlled belt feeders, the speed of the one delivering the clinker being controlled by an Adequate weigher mechanism to ensure correct blending and rate of feed. The blended materials are then conveyed by a belt to the feed chute of a four-compartment grinding mill driven by a 1,200-h.p. British Thomson-Houston synchronous motor through a double-helical gear. It is fitted with water-cooling sprays and dust-extraction equipment.

The cement produced by this mill is taken by air conveyors and a bucket elevator to the four storage silos. Air conveyors and elevators are subsequently used to convey the cement to the packing plant. Here, it can be either delivered in bulk to lorries or packed into bags by a 12-spout Fluxo rotary packer. This has a capacity of 120 tons per hour and delivers the bags to loading conveyors. The output from the plant, for which the main contractors were Sir Alfred McAlpine and Son, Limited, will be delivered by road to the Liverpool area and the Wirral peninsular. Oscar Faber and Partners designed the reinforced concrete work.

*(Editorial comment in Weekly Survey)*

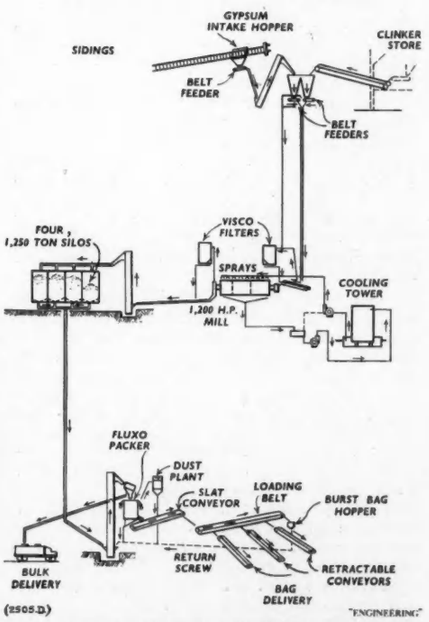
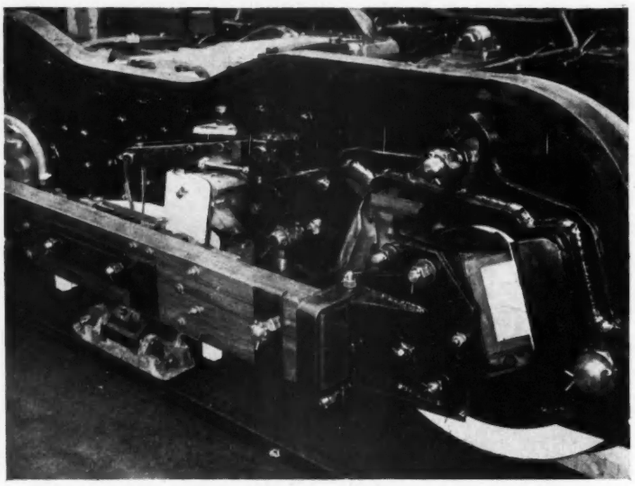



**Fig. 4 Flow diagram of the cement plant. About 5 per cent. of gypsum is added to the clinker and the mixture, when ground, is Portland cement.**



**Bogie with rubber bolster and axle-box suspension for new London tube railway rolling stock.**

# NEW ROLLING STOCK FOR LONDON TUBES

## *Lightweight Construction and Rubber Springing*

Except for 91 cars which were ordered in 1949 the London tube railways are at present operated entirely with pre-war rolling stock, about half of which was ordered in 1938, while of the remainder some has been in service for more than 30 years. Moreover owing to the need for interchangeability with the 1938 stock, the 1949 stock involved no material alterations in the basic design.

It has now been decided that pre-war stock can no longer be allowed to impose limitations on the lay out, and a new design has therefore been prepared, which, while closely following that of the 1938/1949 cars, will include the use of unpainted aluminium alloy for the exterior panelling, bogies incorporating rubber-in-shear springing and fluorescent lighting.

The use of light alloys for the body panelling will enable the weight of each car to be reduced by about one ton. Light steel underframes, as on the 1938 stock, will however, still be used. Whether light alloys should be used in the body frames will subsequently be discussed with the individual builders.

Since 1947 one car on the District Railway has been equipped with a rubber bolster suspension developed by the late Chief Mechanical Engineer (Railways)—Mr. W. S. Graff-Baker—and since 1953 with both rubber bolster and rubber axle-box suspension.* To obtain experience with this system of springing on the tube motor coaches two bogies have been constructed for trial purposes, one of which is illustrated above.

Other improvements are being introduced to achieve a reduction in capital and maintenance costs, as well as greater reliability. These include an alteration in the motor characteristics so as to decrease the energy consumption; the provision of emergency mechanical, instead of automatic, couplers at each end of the three- and four-car units with no through electrical connections; and a simplified pneumatic brake equipment, which includes protection against freezing. Other modifications will comprise a new type of mercury retarder and the employment of laminated plywood beams for mounting the positive shoes and trip cock and for operating the compensating mechanism of the frame-mounted negative shoe gear. A detachable lever, which will be accessible through a floor trap, will enable both the positive and negative shoes to be retracted simultaneously in emergency. Several other features, which were first incorporated in the R stock (surface line) cars, will also be used on the new stock.*

The lighting will consist of a double row of 5-ft. fluorescent lamps placed in a fitting along the centre of the car at ceiling level and closely spaced so as to give even distribution.

As regards the exterior, experience with unpainted surface line cars has led to the decision to abandon the familiar " Underground red " in favour of the natural colour of the aluminium. This will, it is felt, lead to economy in maintenance and facilitate cleaning. The code and train number indicators are to be re-arranged.

Orders for three seven-car trains embodying these modification and made up of three-car and four-car units, is to be placed with each of the following manufacturers: the Birmingham Railway Carriage and Wagon Company, Limited, Smethwick, Staffordshire; the Gloucester Railway Carriage and Wagon Company, Limited, Gloucester; and the Metropolitan-Cammell Railway Carriage and Wagon Company, Limited, Birmingham. It is hoped that these trains will be delivered in the spring of 1956.

* See ENGINEERING, vol. 176, page 830 (1953).

* *Ibid*, Vol. 171, page 705 (1951).

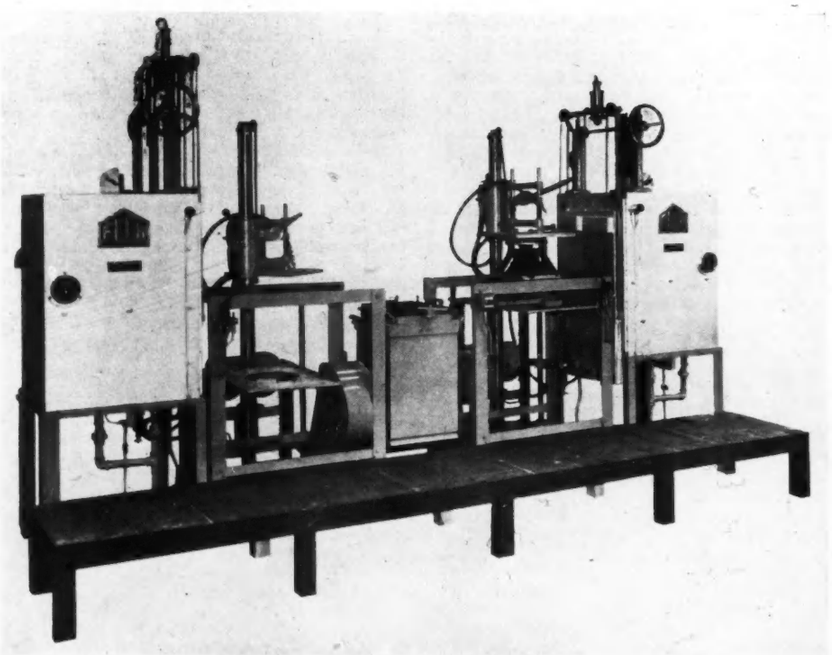
# SHELL MOULDING FOR DEEP PATTERNS

A duplex machine for producing shell moulds up to 13 in. in height or depth has been placed on the market by Fairbairn Lawson Combe Barbour, Limited, Leeds 1. The machine, seen in the accompanying illustration, consists essentially of a central dump box and on each side of this, standing in line, a moulding unit (comprising a gas or electrically-heated oven for preheating and curing the shell moulds) and an adjustable-top mechanism for ejecting the finished mould from the pattern plate.

In the " Shelmolda Altus " machine, as it is called, a first pattern plate is taken ready-heated from one of the two ovens which have pneumatically-operated doors. The pattern plate is blown clean by means of a jet of compressed air and sprayed with a parting agent. The pattern plate is then placed face downwards on the dump box and clamped in position; the dump box, which is pneumatically operated and has a capacity of 220 lb. of moulding material, is turned through an angle of 180 deg. and remains in that position for a predetermined interval controlled by an electronic timing mechanism. After this, the dump box rights itself and the pattern plate is unclamped. The pattern plate with its investment is then placed in an oven for curing.

While this shell mould is being cured a second pattern plate is brought from the second oven, sprayed, invested in the dump box and returned to its oven. The operations are timed in such a manner that when the second invested pattern plate is returned to its oven for curing, the first one is cured and ready to be taken out to have the shell mould removed. This is done by reversing the pattern plate in a specially-constructed holder and applying pressure downwards to the ejector pins. The ejected shell mould is caught on a pneumatically-controlled receptor mechanism and automatically lowered clear of the pattern plate. The latter is then returned to its normal position.

The oven temperatures are thermostatically controlled and can be varied as required, and the interval between reversing the dump box and righting it again can be varied at will by means of an easily set mechanism.



**Duplex shell-moulding machine, comprising central dump box flanked by gas or electric preheating and curing ovens and ejector mechanisms. Patterns 13 in. in height or depth can be used.**

*Labour Notes*

# MORAL WRONG OF UNOFFICIAL STRIKES

Stoppages of work without trade-union approval were firmly condemned by Mr. Herbert Morrison, the deputy leader of the Opposition in a speech at Bath last Saturday.

He said that if reasonable claims for improved conditions were to be successfully negotiated by trade-union leaders and if policies which were economically sensible were to be urged and advanced by the trade-union movement, the loyalty of rank-and-file members to their trade organisations was a vital necessity.

If the ordinary members of the unions did not approve of their executives and office-bearers, there were means available to them for making changes. When, however, men had been elected to responsible positions in their unions, the rank and file surely owed loyalty to them.

In these circumstances, unofficial stoppages of work were morally wrong and could not properly be supported by the Labour Party, or by trade unionists who believed in the principles of collective bargaining and the reaching and concluding of agreements on labour questions. It should be remembered, Mr. Morrison reminded his audience, that the trade-union movement had had to fight hard for many years to obtain these rights and he inferred that they should not lightly be placed in jeopardy.

## STRIKES AGAINST TRADE UNIONISM

Unofficial strikes were defined by Mr. Morrison as those which were not sanctioned by the democratically-elected authorities of the trade-union movement. They were therefore, definitely strikes against trade unionism. Accordingly, when unofficial strike action was urged by mischievous or irresponsible elements, no trade unionist should regard himself as a blackleg, or as being in any way disloyal, if he declined to take part.

In fact, such a man was acting as a good trade unionist should do in circumstances of that nature. Unofficial strikes could hurt the whole nation. They could definitely hurt the labouring sections of the community by causing them much inconvenience. Such strikes could also damage the well-being of the ordinary housewife in a large number of ways.

On this account, Mr. Morrison said, recent attacks on responsible trade-union leaders were to be deplored. The men who were the subject of these attacks had done much to develop the unions. By the knowledge and counsel which they were able to contribute from their day-to-day industrial experience, they had rendered much service to the whole movement.

## SAFER FACTORIES

Measures which had resulted in reducing the accident-frequency rate at one of the largest chemical plants so far constructed, by some 75 per cent. in 25 years, were demonstrated last Saturday, when delegates attending the fifth conference on "Safety in Chemical Works" visited the works of Imperial Chemical Industries, Limited, at Billingham and Wilton.

The conference, which was organised by the Association of British Chemical Manufacturers, took place at Harrogate, and was attended by nearly 450 delegates representing almost every section of the British chemical industry. The principal business of the meeting was the inspection and study of practical accident-prevention schemes in operation at the Billingham and Wilton works.

An outstanding feature of many of the safety devices shown to the visitors was their fundamental simplicity. For example, storage tanks containing dangerous liquids were raised above ground level in order that leakages might the more readily be observed.

Owing to the number of accidents which had occurred while safety belts were being re-adjusted, men engaged on the construction of overhead steelwork were not only equipped with belts, but had safety nets set up beneath them. Electric hand tools were specially designed to work on low voltages and provided with plugs which were not capable of being connected to high-voltage supplies. Experience over a considerable period, it was stated, had shown the value of these simple procedures.

## PROPAGANDA AND COMPETITIONS

The three-day conference was opened last Friday with an introductory address by Dr. I. J. Faulkner, a works manager at Billingham, who emphasised the importance of impressing on all workpeople the urgency of finding safe ways of carrying out their duties.

Propaganda of this nature, Dr. Faulkner considered, was equally as essential as the provision by managements of more and improved safety appliances and of better working conditions. It was found later that, at the works of Imperial Chemical Industries, Limited, this approach to the problem of personal safety in works was strengthened by many kinds of warning devices, varying from red danger boards to flashing neon signs carrying safety notices.

A most effective means of arousing interest among factory employees and of securing their whole-hearted co-operation, Dr. Faulkner stated, was by the introduction of competitions of various kinds, each having some association with the necessity of securing the highest level of accident prevention. One of the most popular of these was a simple, straightforward scheme based on awards for long periods of work free from accidents.

Another idea tried by the company was a competition based on securing maximum safety through tidiness in the works. It was known as the "good housekeeping contest" and prizes were given to the section which was judged to have put up the best showing on a sudden unannounced inspection, held once a year.

The conference closed on Sunday morning, with a brains trust session at which a wide variety of works-safety problems was discussed.

## BRITISH MOTOR CORPORATION'S £8M. INSURANCE SCHEME

Details of a new non-contributory retirement-benefit and life-assurance scheme, available to all non-staff employees, men and women, in the undertakings controlled by the British Motor Corporation Limited, in the United Kingdom, were announced on November 3, by Sir Leonard Lord, the Corporation's chairman.

Under the terms of the scheme, it was stated, the Corporation would pay the full cost of a master insurance policy for the sum assured, amounting to over £8m., at a premium exceeding £400,000 per annum. It was expected that some 45,000 workpeople would benefit by the scheme.

It is provided that non-staff male employees who are aged 25 years or over, but under 60, and have been in the service of a company controlled by the Corporation for a continuous period of three years or over shall, on their retirement at 65, receive £10 in cash for each year of qualifying service. In the case of women, the upper age limit to qualify for entry will be 55 instead of 60, and the retiring age, 60 instead of 65. The scheme provides arrangements for the cash benefits to be exchanged for pensions.

Employees who do not qualify for any of the above-mentioned benefits will be covered, free of cost to themselves, for a death benefit of £100. Employees who are now over 60 years of age, 55 years of age in the case of women workers, and who are, on that account, incapable of ever qualifying for a cash benefit under the above-mentioned arrangements, will be provided with a life benefit of £100, and considered for further benefits when the time of their retirement arrives.

## LONDON SHIP REPAIRERS REMAIN ON STRIKE

Some eight thousand men involved in the strike of ship repairers in the Thames region are to remain idle, according to a decision taken at a mass meeting in central London on Sunday.

About half the men on strike took part in a demonstration and later passed a resolution claiming that they represented all trades within the Port of London ship-repairing industry and stating that they considered that the employers were adopting an "irresponsible attitude" towards the men's "just and reasonable" demands. In those circumstances, the resolution continued, the men would remain idle until the employers conceded their redundancy proposals.

The trouble originated in a redundancy dispute over the dismissal of five electricians in the employ of a London ship-repairing firm. This led to some 500 men engaged on electrical-repairs to ships in the Port of London ceasing work on September 20, as a protest. The strike spread rapidly during the following weeks.

It was claimed that the men dismissed, who are members of the Electrical Trades Union, had been discharged out of turn and that the custom of discharging first men who were engaged last had been broken.

The men now involved in the dispute, which was given official recognition early in October, belong to 15 trade unions, all members of the Confederation of Shipbuilding and Engineering Unions. These bodies are claiming that their right to be consulted when questions of redundancy arise should be recognised by employers.

## INQUIRY COURT'S PROPOSALS ON DOCK DISPUTE

A number of ways in which friction between employers and workpeople regarding overtime in the dock industry might be substantially reduced are put forward by the court of inquiry in their report to the Minister of Labour.

It is suggested by the court that arrangements respecting such matters as the giving of notice where overtime is required, and the provision of substitutes for dockers not willing to work overtime, should be clearly defined. The same proposals apply to the working of gangs with short numbers and to the definition of certain broad principles which would be accepted as valid reasons for declining to work overtime.

The court state that they fully appreciate that the view that overtime in the dock industry should be regarded as voluntary is held sincerely and strongly by large numbers of men, as well as by their trade unions, but they point out that no attempt was made to press the matter to a definite conclusion until January of this year.

They reaffirm the doubt expressed in their interim report as to whether many of those who feel that the dock labour scheme imposes an unfair burden upon them have reflected on the seriousness of acting in disregard to the industry's conciliation machinery and in breach of the scheme. They also question whether these men have sufficiently reflected upon the advantages of upholding the scheme as a whole.

The report was published as a White Paper last Friday. (H.M.S.O., price 9*d.* net.)

# NOTICES OF MEETINGS

### Aslib

LONDON
"The Work of International Organisations and Foreign Documentation Centres," by Dr. Alexander King. The Royal Society of Arts, John Adam-street, Strand, W.C.2. Mon., Nov. 15, 6 p.m.

### Association of Supervising Electrical Engineers

LONDON
"Application of Lifts for Modern Traffic Conditions," by W. A. Dixie. Annual Joint Meeting with Institution of Engineers-in-Charge. Magnet House, Kingsway, W.C.2. Tues., Nov. 16, 6.15 p.m.
MANCHESTER
"Industrial and Commercial Tariffs," by A. S. Verity. Manchester Branch. Engineers' Club, Albert-square, Manchester. Wed., Nov. 17, 7.30 p.m.
NOTTINGHAM
"Practical Application of Rectifier Elements," by A. R. Weston. Nottingham Branch. East Midlands Electricity Board's Showrooms, Smithy-row, Nottingham. Wed., Nov. 17, 7.30 p.m.
SOUTHAMPTON
Film Evening. Southampton Branch. Polygon Hotel, Southampton. Wed., Nov. 17, 8.15 p.m.

### British Institution of Radio Engineers

CARDIFF
"Techniques of Power Measurements from Direct Current to 5 Mc/s.," by G. F. Lawrence. South Wales Section. Cardiff College of Technology, Cathays Park, Cardiff. Wed., Nov. 17, 6.30 p.m.

### Chemical Society

LONDON
"Molecular Re-arrangements," by Professor M. J. S. Dewar. Tilden Lecture. Imperial College of Science and Technology, South Kensington, S.W.7. Thurs., Nov. 18, 7.30 p.m.
GLASGOW
"The Chemical Nature of Some Metal Alkyls," by Professor G. E. Coates. Royal Technical College, Glasgow. Fri., Nov. 19, 7.15 p.m.

### Diesel Engine Users Association

LONDON
"Notes on the Performance of Some Two-Stroke Oil Engines," by Professor S. J. Davies and M. A. Plint. Caxton Hall, Westminster, S.W.1. Thurs., Nov. 18, 2.30 p.m.

### Engineers' Guild

LONDON
Film Evening, and Open Discussion on the Guild and its Work. Metropolitan Branch. Caxton Hall, Westminster, S.W.1. Wed., Nov. 17, 6 p.m.

### Illuminating Engineering Society

BRADFORD
"Industrial Colour-Matching Problems," by A. Wilcock. Leeds Centre. Offices of the Yorkshire Electricity Board, 45-53 Sunbridge-road, Bradford. Wed., Nov. 17, 6.15 p.m.
GLOUCESTER
"Lighting for Enjoyment," by T. O. Freeth. Gloucester and Cheltenham Centre. Offices of the General Electric Co., Ltd., 2 St. Aldate-street, Gloucester. Tues., Nov. 16, 6.30 p.m.
LIVERPOOL
"Lighting for Production," by J. W. Howell. Liverpool Centre. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Tues., Nov. 16, 6.30 p.m.

### Incorporated Plant Engineers

BLACKBURN
"Gas Turbines," by J. R. Needham. Blackburn Branch. Golden Lion Hotel, Blackburn. Thurs., Nov. 18, 7.30 p.m.
CARDIFF
Discussion on "Instrumentation and Thermostatic Controls." South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., Nov. 16, 7.15 p.m.
GLASGOW
"Assembly, Use and Maintenance of Chain Slings," by W. G. Biggart. Glasgow Branch. Scottish Building Centre, 425-427 Sauchiehall-street, Glasgow. Wed., Nov. 17, 7 p.m.
LIVERPOOL
"The Factory Act and the Plant Engineer," by A. Mills. Merseyside and North Wales Branch. Radiant House, Bold-street, Liverpool. Thurs., Nov. 18, 7.15 p.m.
ROCHESTER
"Fan Characteristics, Especially Their Application to Boiler Plant," by C. E. Knight. Kent Branch. Bull Hotel, Rochester. Wed., Nov. 17, 7 p.m.

### Institute of British Foundrymen

LONDON
"Some Foundry Problems," by G. Rogers. London Branch. Waldorf Hotel, Aldwych, W.C.2. Wed., Nov. 17, 7.30 p.m.
BIRMINGHAM
"The Hardening of Moulds and Cores by the $CO_2$ Process," by Dr. D. V. Atterton. Birmingham Branch. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., Nov. 15, 7.15 p.m.

### Institute of Fuel

BIRMINGHAM
"Modern Gas-Turbine Practice," by H. Farrington. Midland Section. James Watt Memorial Institute, Birmingham. Tues., Nov. 16, 6 p.m.
SHEFFIELD
"Flame Radiation Research," by Professor M. W. Thring. Yorkshire Section. Royal Victoria Station Hotel, Sheffield. Wed., Nov. 17, 2.30 p.m.

### Institute of Marine Engineers

BIRKENHEAD
"Marine Diesel Engines," by A. G. Arnold. Merseyside and North-Western Section. Birkenhead Technical College, Birkenhead. Wed., Nov. 17, 7 p.m.
GREENOCK
"Diesel Hydraulic Propulsion," by F. J. Mayor. Scottish Section. The Lorne, Blackhall-street, Greenock. Tues., Nov. 16, 7.30 p.m.

### Institute of Petroleum

LONDON
Cadman Memorial Lecture on "Winning Petroleum: A Story of British-American Co-operation," by C. A. P. Southwell. Royal Institution, Albemarle-street, W.1. Wed., Nov. 17, 4.30 p.m.

### Institute of Road Transport Engineers

LONDON
"An Approach to the Organisation and Operation of a Large Composite Fleet," by R. H. Patman. Royal Society of Arts, John Adam-street, W.C.2. Thurs., Nov. 18, 6.30 p.m.
LIVERPOOL
Discussion on "Disc Brake." North-West Centre. Adelphi Hotel, Liverpool. Wed., Nov. 17, 7.30 p.m.

### Institution of Civil Engineers

LONDON
"Present Trends in the Design of Pressure Tunnels and Shafts for Underground Hydro-Electric Power Stations," by Dr. Charles Jaeger. Tues., Nov. 16, 5.30 p.m.
LOUGHBOROUGH
"Prestressed Concrete in Practice," by J. Singleton Green. Midlands Association. The Old College, Loughborough. Wed., Nov. 17, 7 p.m.

### Institution of Electrical Engineers

LONDON
Discussion on "Has Nuclear Fission a Future as a Source of Industrial Power?" Opened by Sir Harold Roxbee Cox. Mon., Nov. 15, 5.30 p.m.
Celebration of the Jubilee of the Thermionic Valve. Opening Address by the Marquess of Salisbury; "The Genesis of the Thermionic Valve," by Professor G. W. O. Howe; and "Thermionic Devices from the Development of the Triode up to 1939," by Sir Edward Appleton, at 2.30 p.m. "Developments in Thermionic Devices Since 1939," by Dr. J. Thomson, at 5.30 p.m. Tues., Nov. 16.
"The Use of Electricity in the Production of Calcium Carbide," by C. J. Beavis. Utilization Section. Thurs., Nov. 18, 5.30 p.m.
LEEDS
"Measurement of the Winding Resistances of a 132-kV Power Transformer in Service," by K. J. R. Wilkinson and J. D. Harmer. North Midland Centre. Offices of Yorkshire Electricity Division, 1 Whitehall-road, Leeds. Tues., Nov. 16, 6.30 p.m.

### Institution of Engineering Inspection

WOLVERHAMPTON
"Shell Moulding," by M. C. Dixon. Wolverhampton Branch. Compton Grange, Compton-road, Wolverhampton. Wed., Nov. 17, 7.30 p.m.

### Institution of Engineers-in-Charge

LONDON
"Application of Lifts for Modern Traffic Conditions," by W. A. Dixie. Annual Joint Meeting with the Association of Supervising Electrical Engineers. Magnet House, Kingsway, W.C.2. Tues., Nov. 16, 6.15 p.m.

### Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"The Choice of Electrodes for Ship Welding," by G. Zoethout. Tues., Nov. 16, 7.30 p.m.

### Institution of Heating and Ventilating Engineers

LEEDS
"Steam Boiler Operation, Inspection and Insurance," by W. A. Mills. Yorkshire Branch. Hotel Metropole, Leeds. Wed., Nov. 17, 7.30 p.m.
PRESTON
"Radiant Heating," by A. Bates. Manchester Branch. County Hall, Preston. Fri., Nov. 19, 6.30 p.m.

### Institution of Locomotive Engineers

LONDON
"A Modern Hydraulic Drive for Locomotives," by R. H. Fett. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Nov. 17, 5.30 p.m.

### Institution of Mechanical Engineers

LONDON
Discussion on "Measurement of Flow," Hydraulics Group. Tues., Nov. 16, 6.45 p.m.
James Clayton Lecture on "Guided Missiles," by G. W. H. Gardner. Fri., Nov. 19, 5.30 p.m.
"Expansion Provision for Pipe Lines," by V. Westerman. London Graduates' Section. Thurs., Nov. 18, 6.30 p.m.
BRIGHTON
Discussion on "The Future of the Compression-Ignition Engine for Small Road Vehicles," opened by J. T. Pitchford. Southern Branch. Brighton Technical College, Brighton. Wed., Nov. 17, 7 p.m.
CHESTERFIELD
"Nodular Cast Iron: Its Present Position and Future Prospects as an Engineering Material, Especially Its Suitability for Crankshafts," by S. B. Bailey. East Midlands Branch. College of Technology, Chesterfield. Wed., Nov. 17, 7.30 p.m.
GLASGOW
"Problems in the Design of an Economical Automobile Gearbox," by T. C. F. Stott. Scottish A.D. Centre. 39 Elmbank-crescent, Glasgow. Mon., Nov. 15, 7.30 p.m.
LEEDS
"Earth-Moving," by R. W. Ladbrooke. North-Eastern A.D. Centre. The University, Leeds. Wed., Nov. 17, 7.30 p.m.

### Institution of Mining and Metallurgy

LONDON
"Notes on an Experimental Stoping Block at Roan Antelope Copper Mines," by A. W. S. Schumann; "Flotation of Oxidised Ores of Lead, Copper and Zinc," by Maurice Rey; and "The Effect of Temperature on the Recovery of Kyanite by Froth Flotation," by W. H. Passmore. Geological Society, Burlington House, Piccadilly, W.1. Thurs., Nov. 18, 5 p.m.

### Institution of Production Engineers

BIRMINGHAM
"Production and Properties of Titanium and Titanium Alloys," by R. L. P. Berry. Birmingham Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Wed., Nov. 17, 7 p.m.
GLASGOW
"The Basic Nomenclature of Cutting Tools," by G. V. Stabler. Glasgow Section. 39 Elmbank-crescent, Glasgow, C.2. Thurs., Nov. 18, 7.30 p.m.
LIVERPOOL
"Shell Moulding," by D. N. Buttrey. Liverpool Section. Exchange Hotel, Liverpool. Wed., Nov. 17, 7.30 p.m.
MANCHESTER
"The Practical Application of Production Engineering Research," by Dr. D. F. Galloway. Manchester Section. College of Technology, Sackville-street, Manchester. Mon., Nov. 15, 7.15 p.m.
NEWCASTLE-UPON-TYNE
"Practical Uses of Electronics in Industry," by K. A. Zandstra. North-Eastern Section. Neville Hall, Newcastle-upon-Tyne. Mon., Nov. 15, 7 p.m.
SOUTHAMPTON
"Provocative Tooling Methods for Aircraft," by S. P. Woodley. Southern Section. Polygon Hotel, Southampton. Thurs., Nov. 18, 7.15 p.m.

### Institution of the Rubber Industry

PORTSMOUTH
"Rubber and Plastics in the Aircraft-Tank Industry," by J. P. Griffiths. Southern Section. Municipal College, Portsmouth. Wed., Nov. 17, 7.30 p.m.

### Institution of Sanitary Engineers

LONDON
"Practical Aspects of Planning and Construction of Sewerage Schemes," by W. D. Haworth. Public Works and Municipal Services Congress, Olympia, W.14. Mon., Nov. 15, 3.15 p.m.

### Institution of Structural Engineers

GLASGOW
"Influence of Welding on Steel Building Structures," by S. M. Reisser. Scottish Branch. 39 Elmbank-crescent, Glasgow, C.2. Wed., Nov. 17, 7 p.m.
LEEDS
"Aluminium-Alloy Structures," by D. V. Pike. Yorkshire Branch. Great Northern Hotel, Leeds. Wed., Nov. 17, 6.30 p.m.

### Junior Institution of Engineers

LONDON
Chairman's Address on "Engineering Plant in Buildings," by S. G. Clark. Fri., Nov. 19, 7 p.m.

### Liverpool Metallurgical Society

LIVERPOOL
"Fracture of Metals," by C. E. Phillips. 9 The Temple, 24 Dale-street, Liverpool. Thurs., Nov. 18, 7 p.m.

### Modular Society

LONDON
Annual General Meeting, and Open Discussion. Royal Society of Arts, John Adam-street, W.C.2. Wed., Nov. 17, 7.30 p.m.

### Reinforced Concrete Association

LONDON
"Composite Construction," by Felix J. Samuely. 11 Upper Belgrave-street, S.W.1. Wed., Nov. 17, 6 p.m.

### Royal Aeronautical Society

LONDON
"Uses of the 'Ace' Computer," by Dr. E. T. Goodwin. Tues., Nov. 16, 7 p.m.

### Royal Institution

LONDON
"Models of Metal Structure," by Sir Lawrence Bragg. Fri., Nov. 19, 9 p.m.

### Royal Meteorological Society

LONDON
Discussion on "Water Supply." Wed., Nov. 17, 4.45 p.m.

### West of Scotland Iron and Steel Institute

GLASGOW
"Direct-Reading Spectrographic Analysis of Ferrous Metals, with Special Reference to the Quantometer," by A. Argyle. Fri., Nov. 19, 6.45 p.m.

**The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated.** Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Aslib, 4 Palace-gate, London, W.8. (WEStern 6321.)
Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Diesel Engine Users Association, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Engineers' Guild, 78 Buckingham-gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Inspection, 28 Victoria-street, London, S.W.1. (ABBey 3794.)
Institution of Engineers-in-Charge, 100 Earlsfield-road, London, S.W.18. (BATtersea 1394.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2. (MONarch 2096.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Institution of Sanitary Engineers, 118 Victoria-street, London, S.W.1. (VICtoria 3017.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Liverpool Metallurgical Society, 55 Tudorville-road, Bebington, Cheshire. (Rock Ferry 4878.)
Modular Society, 22 Buckingham-street, London, W.C.2. (TRAfalgar 4567.)
Reinforced Concrete Association, 94-98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
West of Scotland Iron and Steel Institute, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)